Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

December, 1951

Volume 39 Number 12

National Bureau of Standards

UNROLLING MINIATURE RESISTORS

inch wide adhesive-tape resistor is applied from a spool to a silver-ceramic chassis, pressed into place, and cut to length. After oven he resistor darkens (see left sample).

PROCEEDINGS OF THE I.R.E.

Systems Engineering Management
HF Gas-Discharge Breakdown
Simulation in System Design
CAA VHF Omnirange
Design of Radar Receivers
Automatic RF Repeater System
Direction Finder and Flow Meter
Frequency Dividers
Long-Distance Backscatter
Space-Charge Effects in Tetrodes
Space-Charge Effects in Klystrons
Circuit for Generating Polynomials
Antenna Current Distribution
High Speed K-Band Switch
Abstracts and References
Annual Index

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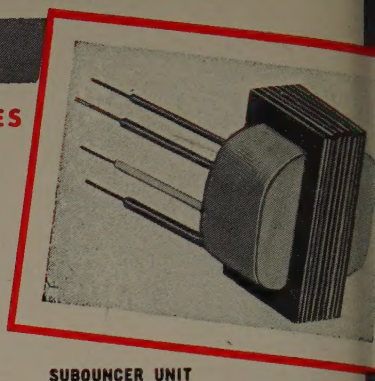
The Institute of Radio Engineers

MINIATURE COMPONENTS FROM STOCK...

SUBOUNCER UNITS

FOR HEARING AIDS...VEST POCKET RADIOS...MIDGET DEVICES



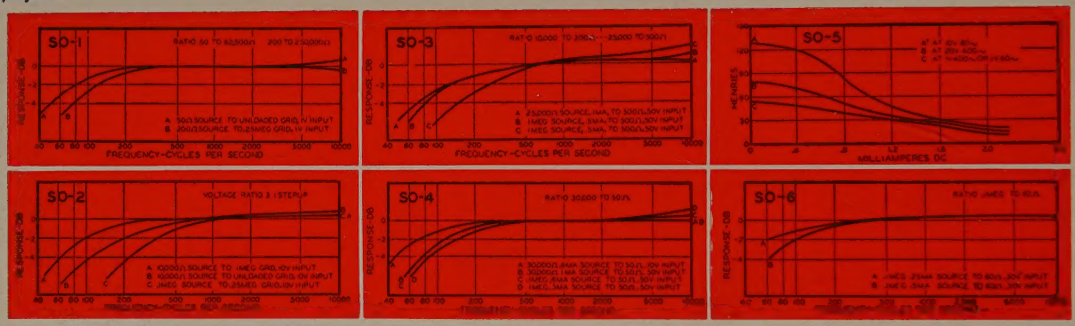
SUBOUNCER UNIT
Dimensions....9/16" x 5/8" x 7/8"
Weight.....03 lb.

UTC Sub-Ouncer units fulfill an essential requirement for miniaturized components having relatively high efficiency and wide frequency response. Through the use of special nickel iron core materials and winding methods, these miniature units have performance and dependability characteristics far superior to any other comparable items. They are ideal for hearing aids, miniature radios, and other types of miniature electronic equipment.

The coils employ automatic layer windings of double Formex wire...in a molded Nylon bobbin. All insulation is of cellulose acetate. Four inch color coded flexible leads are employed, securely anchored mechanically. No mounting facilities are provided, since this would preclude maximum flexibility in location. Units are vacuum impregnated and double (water proof) sealed. The curves below indicate the excellent frequency response available. Alternate curves are shown to indicate operating characteristics in various typical applications.

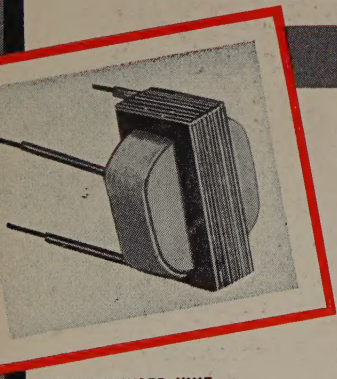
Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SO-1	Input	+ 4 V.U.	200 50	0	250,000 62,500	16	2650	$6.50
SO-2	Interstage/3:1	+ 4 V.U.	10,000	0	90,000	225	1850	6.50
*SO-3	Plate to Line	+ 20 V.U.	10,000 25,000	3 mil. 1.5 mil.	200 500	1300	30	6.50
SO-4	Output	+ 20 V.U.	30,000	1.0 mil.	50	1800	4.3	6.50
SO-5	Reactor 50 HY at 1 mil. D.C. 3000 ohms D.C. Res.							5.50
SO-6	Output	+ 20 V.U.	100,000	.5 mil.	60	3250	3.8	6.50

*Impedance ratio is fixed, 1250:1 for SO-1, 1:50 for SO-3. Any impedance between the values shown may be employed.



SUB-SUBOUNCER UNITS

FOR HEARING AIDS AND ULTRA-MINIATURE EQUIPMENT

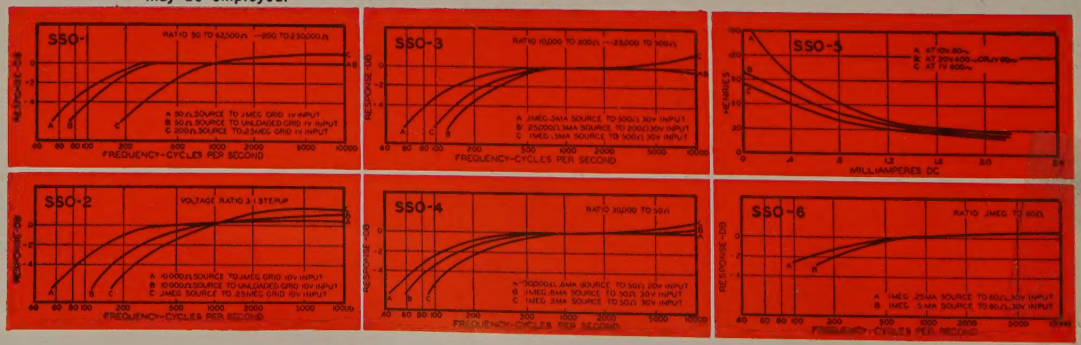


SUB-SUBOUNCER UNIT
Dimensions....7/16" x 3/4" x 5/8"
Weight.....02 lb.

UTC Sub-SubOuncer units have exceptionally high efficiency and frequency range in their ultra-miniature size. This has been effected through the use of specially selected Hiperm-Alloy core material and special winding methods. The constructional details are identical to those of the Sub-Ouncer units described above. The curves below show actual characteristics under typical conditions of application.

Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SSO-1	Input	+ 4 V.U.	200 50	0	250,000 62,500	13.5	3700	$6.50
SSO-2	Interstage/3:1	+ 4 V.U.	10,000	0	90,000	750	3250	6.50
*SSO-3	Plate to Line	+ 20 V.U.	10,000 25,000	3 mil. 1.5 mil.	200 500	2600	35	6.50
SSO-4	Output	+ 20 V.U.	30,000	1.0 mil.	50	2875	4.6	6.50
SSO-5	Reactor 50 HY at 1 mil. D.C. 4400 ohms D.C. Res.							5.50
SSO-6	Ouptut	+ 20 V.U.	100,000	.5 mil.	60	4700	3.3	6.50

*Impedance ratio is fixed, 1250:1 for SSO-1, 1:50 for SSO-3. Any impedance between the values shown may be employed.



United Transformer Co.
150 VARICK STREET
NEW YORK 13, N. Y.

Forty Years — Sets the Pace . . .

1912 1952

is the theme of the 1952 IRE National Convention and Radio Engineering Show, marking the progress of IRE's first forty years' service.

— *What this Annual Event Means* —

To the Member and Visitor:

The Conference and Show provide a refresher course on the progress and pace of the science and engineering application of radio in television, broadcasting, electronics and defense.

In no other way can one feel the pulse-beat of a great industry as easily, and learn as much as in the four days of this meeting. From theory in the technical papers, to practice in engineering demonstrations of the exhibits, this is the modern, fast way to keep up-to-date.

So convinced of this is our industry that last March 5,082 different firms sent their engineers and executives to this conference. 15,258 attended sessions of their choice. Of the 22,919 who registered, all but ¼ of 1% visited the exhibits. 7,924 were IRE Members. This means that nearly 30% of the total membership of this engineering society attended its annual national convention.

Skillfully grouped technical papers map the advances in every field of radio, from guided missiles to television, and from communications to industrial electronics. This year, more than 200 papers will be presented, using five lecture halls—giving engineers an equivalent coverage of five conferences in one.

△

Audience at Technical Papers Session

To the Radio Industry:

What is the significance to an industry when 277 exhibitors meet in one place for four days to show their technical products to engineers? It means that IRE has produced through its meeting an economically sound market-place.

These exhibitors are the top 15% of the manufacturers supplying the field, who produce 90% of the products engineers buy! Is it any wonder that the audience comes to such a concentration of equipment, component and instrument exhibits? Think of the time saved!

Here is the record:

1947—177 firms met 12,013 visitors
1948—180 firms met 14,459 visitors
1949—225 firms met 15,710 visitors
1950—253 firms met 17,689 visitors
1951—277 firms met 22,919 visitors
(More than 300 firms in 1952)

When the manufacturer's engineer meets the buyer's engineer, problems are solved and sales are made. In a technical industry, only the engineer can "set the specs" and he is the man usually too busy to see a salesman. But at the Radio Engineering Show, he comes to see what's new.

△

Main Floor Exhibits—1951

"Come Again"

The IRE National Convention and Radio Engineering Show

March 3-6, 1952, Waldorf Astoria Hotel and Grand Central Palace, New York

The Institute of Radio Engineers

1 East 79th Street, New York 21, N.Y.

Exhibits Dept., 303 West 42nd Street, New York 18

PROCEEDINGS OF THE I.R.E. December, 1951, Vol. 39, No. 12. Published monthly by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price per copy: members of the Institute of Radio Engineers $1.00; non-members $2.25. Yearly subscription price: to members $9.00; to non-members in United States, Canada and U.S. Possessions $18.00; to non-members in foreign countries $19.00. Entered as second class matter, October, 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927. Printed in U.S.A.

Table of Contents will be found following page 64A

A high percentage of today's dual-shaft and special-purpose control requirements can be handled fast and economically by combinations or adaptations of *standard* Stackpole .5 and .6 watt units and *standard* Stackpole switches. Beyond these, however, Stackpole offers full facilities for matching special needs—including continuously adjustable Stackpole Carbon Regulator Discs (carbon piles) for critical power resistance and voltage control uses.

Electronic Components Division

STACKPOLE CARBON COMPANY

St. Marys, Pa.

FIXED RESISTORS • VARIABLE RESISTORS • IRON CORES
CERAMAG® (non-ferrous) CORES • MOLDED COIL FORMS
LINE and SLIDE SWITCHES • GA "GIMMICK" CAPACITORS

Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups, and some closely related groups *which include exhibits.*

△

IRE National Convention & Radio Engineering Show
March 3-6, 1952
Waldorf-Astoria Hotel and Grand Central Palace
New York City

△

NEREM
Saturday, May 10, 1952
Copeley Plaza Hotel
Boston, Mass.
New England Radio Engineering Meeting
Gen. Chairman: Alfred J. Pote
71 West Squantum St.
N. Quincy, Mass.

△

National Conference on Airborne Electronics
May 12, 13 & 14, 1952
Hotel Biltmore, Dayton, Ohio
Exhibits: Paul D. Hauser
1430 Gascho Drive, Dayton 3.

△

4th Southwestern IRE Conference
May 16, 17, 1952
Rice Hotel, Houston, Texas
Exhibits: Gerald L. K. Miller
1622 W. Alabama
Houston 6, Tex.

△

Western Electronic Show and IRE Regional Convention
August 27, 28 & 29, 1952
Long Beach, Calif.
Exhibits: Heckert Parker
215 American Avenue
Long Beach 2, California

△

National Electronic Conference
Sept. 29, 30, Oct. 1, 1952
Hotel Sherman, Chicago, Ill.

△

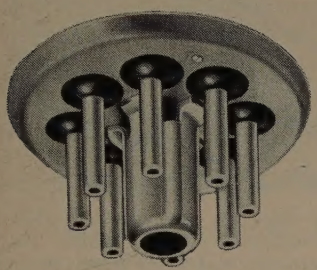
Cincinnati Convention on Television
April 19, 1952
Cincinnati, Ohio

FUSITE MULTIPLE TERMINAL PANELS

for Plug-in Applications of

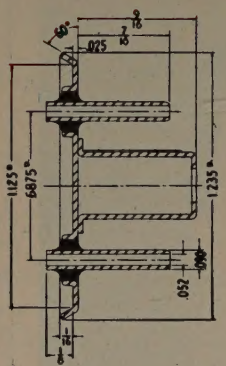
HERMETICALLY SEALED ELECTRICAL COMPONENTS

Plug-in type of terminals are becoming increasingly popular because of the easy, fool-proof nature of their use. The tongued centering key fits a correspondingly grooved socket. FUSITE offers a large variety of this style terminal ranging from 2 to 20 electrodes and in several flange sizes and treatments. All terminals are regular FUSITE glass-to-steel construction. Sockets are available for all FUSITE Plug-in terminals.



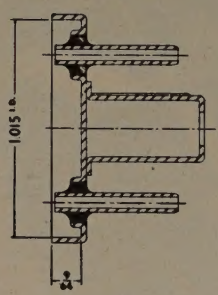
7-900 HTO Series
2000 V (RMS)
Available 2 to 8 hollow tube electrodes.

Available Flange Treatments



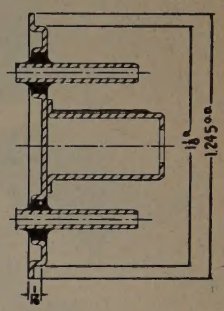
TYPE 1

7-900 HTO Series with standard 60° solder flange.



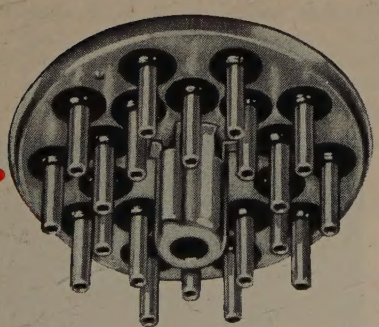
TYPE 2

7-900 HTO Series with special 90° solder flange. Caps 1" O.D. can. Also available as Type 2B to cap 1.540"O.D. can. and Type 2C to cap 1⅝" O.D. can.

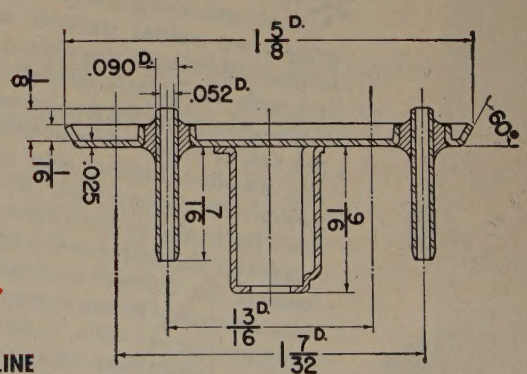


TYPE 3

7-900 HTO Series with special offset flat solder flange.



7-2300 HTO Series
2000 V (RMS)
Available 11 to 20 hollow tube electrodes.



Write for Catalog

OF COMPLETE LINE
AND ENGINEERING DETAILS -- DEPT. A

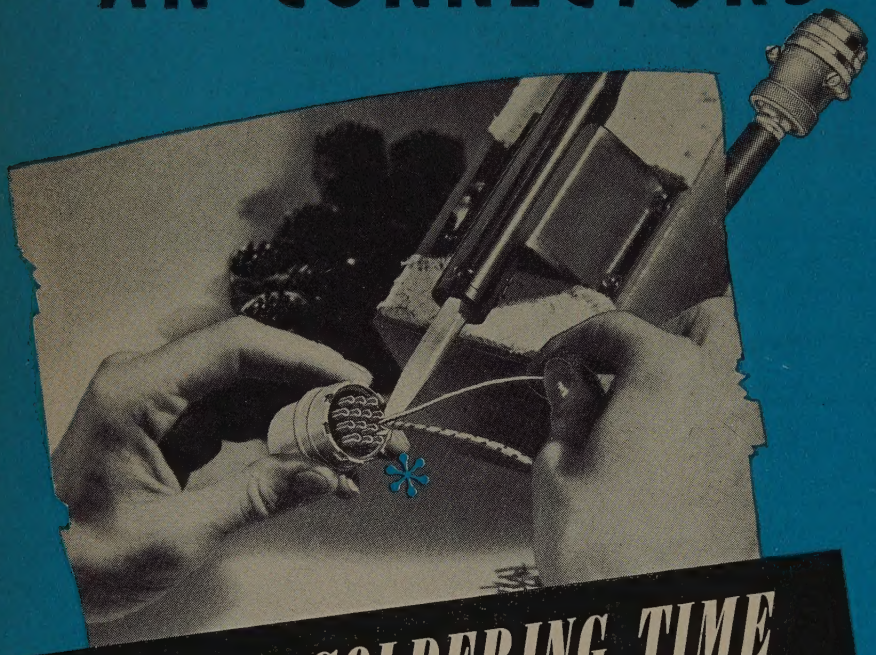
INSULATE ELECTRICALLY
GLASS TO METAL
FUSITE
TERMINALS
PROTECT PRODUCT PERFORMANCE
SEAL HERMETICALLY

THE FUSITE CORPORATION
6028 FERNVIEW AVENUE - CINCINNATI 13, OHIO

EXTRA* features

with AMPHENOL

AN CONNECTORS



SAVES SOLDERING TIME with CONTACT ALIGNMENT

*AMPHENOL superior non-rotating contacts are designed for easy wiring. The pre-tinned solder pockets are uniformly aligned making it possible to start soldering with the bottom contacts and work up without turning the connector. This allows the solder to set without movement assuring positive contact and strength of the completed connection. By applying the iron tip to the contact from underside, the operator can observe the flow of solder between the contact and wire. In addition, the economy of movement on the solderer's part saves 40% in assembly time and lowers production costs considerably.

Another example of outstanding product design by AMPHENOL.

AMPHENOL

AMERICAN PHENOLIC CORPORATION

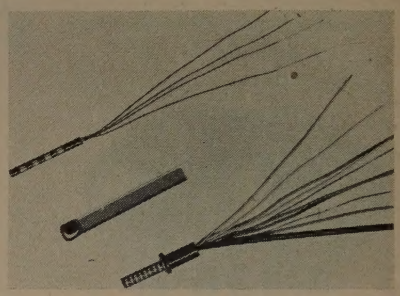
1830 SOUTH 54TH AVENUE • CHICAGO 50, ILLINOIS

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

Sub-Miniature Sliprings

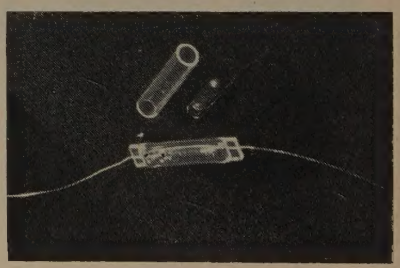
Naer Corp., 631 S. Sepulveda Blvd., W. Los Angeles 49, Calif., has produced a new line of sliprings. These rings are fabricated with Formex magnet wire because of the physical properties of its insulating film, plus a coating of NAER L-45 insulation, making them practical for use in all communications, gear and industrial electronic equipment. It has flexibility, exceptional dielectric strength, heat resistance, abrasion and shock resistance.



These sliprings are molded with a special compound NC-101 which has a Tensile strength, psi 4,000–4,400; flexural strength, psi 6,000–6,500; Rockwell Hardness (M scale) 27.0; heat distortion temperature of 225–235°F. Special molding forms eliminate shrinking, swelling, and temperature effects.

Nylon Tubing for Thermistors

Anchor Plastics Co., Inc., 533–541 Canal St., New York 13, N. Y., announces that extruded Nylon tubing about the diameter of a lead pencil is being employed to encase one type of glass-enclosed bead thermistor used in time-delay circuits.



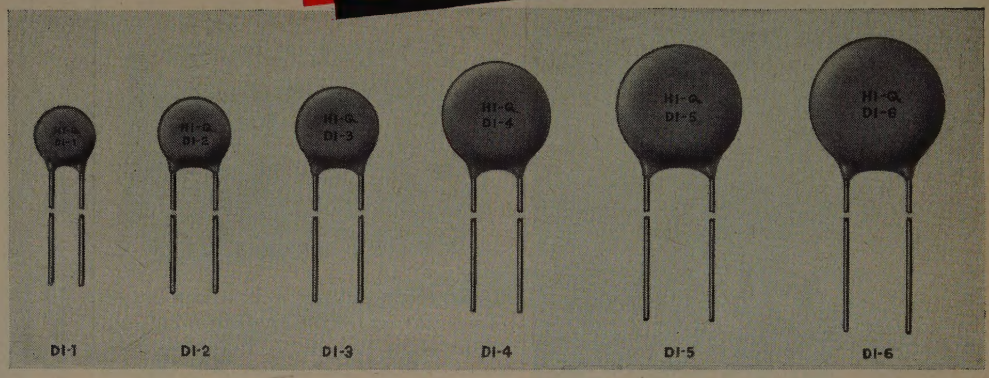
The thermistor is inserted in a length of tubing and the ends of the tubing pressed flat under heat in an hydraulic press for a given length of time. This gives Nylon the "set" desired.

The tubing provides mechanical protection of the glass bulb, electrical insulation (no metal end caps are required), and protects against straining the glass bulb through flexure of the connecting leads. Nylon readily takes the shape desired and is heat resistant.

Heat resistance is a factor because the connecting leads are soldered during assembly into circuits and the apparatus in which the thermistors are used must operate properly over a wide range of temperatures.

(Continued on page 28A)

NEW from HI-Q*



Illustrations approximately actual size.

Temperature Compensating DISK Capacitors

Capacity range from 475 mmf on the DI-6 N1400 material down to .3 mmf on the DI-1 size with tolerances of ± 5% or greater. Conservatively rated for working voltage at 500 volts DC and flash tested at 1500 volts DC. Insulation resistance at 100 volts is well over 10,000 megohms. Electrodes are fired directly to the low loss dielectric and are coated with a non-hydroscopic phenolic for protection against moisture and high humidities. Conform to RTMA Class 1 ceramic capacitors.

Extended Temperature Compensating DISK Capacitors

Produced from a recently developed group of extended coefficient ceramics, this type of **HI-Q** Disk permits a much wider temperature compensating range than was possible on the formerly available normal linear temperature coefficient ceramics. Specifically developed for applications requiring a very large gradient of capacity versus temperature. These new **HI-Q** Disks exhibit relatively higher dielectric constants permitting capacities in the range intermediate between the high K and linear or normal group of ceramics. The Q (a minimum of 250 at 1 megacycle) is somewhat lower than the Class 1 ceramics. It has, therefore, not been classified by RTMA as Class 1. However, characteristics are superior to by-pass Class 2 ceramics.

ALL HI-Q DISK CAPACITORS COME IN THESE SIX SIZES

Type	Diameter	Lead Width	Thickness
DI-1	5/16" Max.	3/16" ± 1/16"	5/32" Max.
DI-2	3/8" Max.	1/4" ± 1/16"	5/32" Max.
DI-3	7/16" Max.	1/4" $+\frac{1/8"}{0"}$	5/32" Max.
DI-4	19/32" Max.	1/4" $+\frac{1/8"}{0"}$	5/32" Max.
DI-5	11/16" Max.	3/8" ± 1/8"	5/32" Max.
DI-6	3/4" Max.	3/8" ± 1/8"	5/32" Max.

Companion Lines to the Popular HI-Q By-pass DISK Capacitors

The widely used **HI-Q** By-pass Disks are fixed ceramic dielectric capacitors which meet RTMA Class 2 specifications. They are available in the complete capacity range of from .3 mmf to 30,000 mmf. Standard tolerances of 5% thru 20% where applicable can be furnished.

Write for Engineering Bulletin Giving Details of all HI-Q DISK Capacitors

HI-Q*

*Trade Mark Registered, U. S. Patent Office

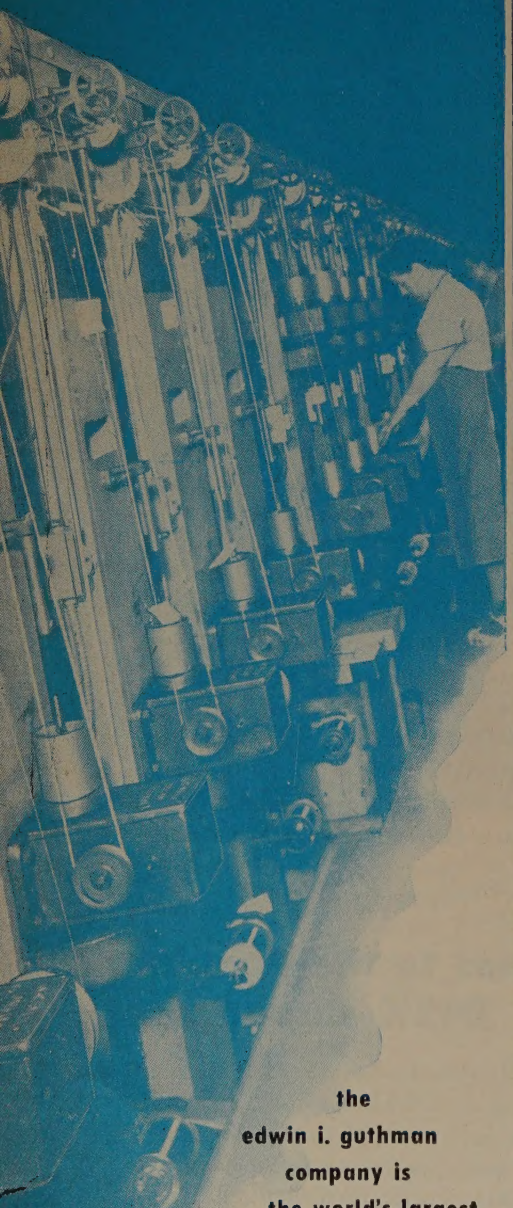
Electrical Reactance Corp.
OLEAN, N. Y.

SALES OFFICES: New York, Philadelphia, Detroit, Chicago, Los Angeles

PLANTS: Olean, N. Y., Franklinville, N. Y. Jessup, Pa., Myrtle Beach, S. C.

guthman coil quality

controlled from raw materials to finished components!



the edwin i. guthman company is the world's largest independent maker of coils and other basic electronic components

edwin i. guthman & co., inc.

15 s. throop st. chicago 7.. CH 3-1600

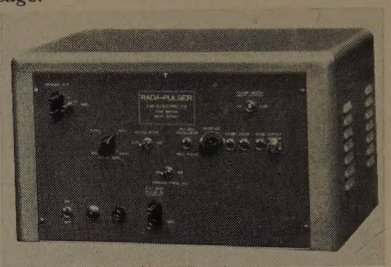
also attica, indiana .

News—New Products

(Continued from page 24A)

Pulsed Carrier Generator

A new pulsed-carrier generator called the RADA-PULSER is offered by **Kay Electric Co.,** 14 Maple Ave., Pine Brook, N. J., to give transient response information in laboratories, on production lines, and in the field. The instrument is engineered for military as well as commercial usage.



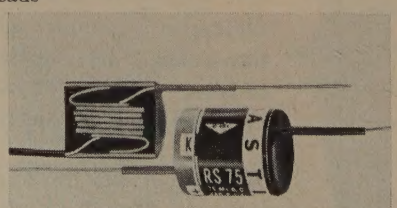
The Rada-Pulser specifications are as follows: carrier frequencies; 30 and 60 mc; pulse widths; 0.1 and 0.25 microseconds; pulse repetition rate; continuously variable from 500 to 2,000 pps; Maximum rf output, approximately 1 volt at 70 ohms; Attenuators; 20 db, 20 db, 10 db switched 10 db continuously variable.

Pulse output is 50 volts at 70 ohms. A jack is provided to permit use of envelope pulses. External modulation: Input terminals provided to permit modulation by other pulse widths from external source. Trigger pulses: Positive and negative furnished ahead of pulsed carrier to trigger oscilloscope sweep circuit. Regulated power supply is built in.

Price: $595.00, F.O.B. factory. Write to manufacturer for additional information and latest catalog.

Molded-In Selenium Rectifiers

Electronic Devices, Inc., Precision Rectifier Div., 429 12th St., Brooklyn 15, N. Y., announces that all ratings up to 200 ma dc output in the Plastisel line of miniature selenium rectifiers are molded in, similar to small tubular capacitors. The outer case is spiral-wound phenolic tubing filled with wax which shows no sign of softening at 100°C. The thermal conductivity of this wax and the low loss plates compensate for the loss of cooling due to molding-in. These rectifiers are manufactured with bare or insulated tin-copper leads



In ratings from 250 to 500 ma dc the standard open-plate construction is used. However, the plates lead to cooler operation and longer life. All open and closed construction stacks are standard in 380 P I U ratings (130 volts ac into a capacitor). They can also be had in other voltage ratings and as doubler units for special applications. All Plastisel rectifiers are guaranteed for 1,000 hours or 1 year, whichever occurs first.

(Continued on pgae 56A)

Where the Requirements are Extreme...

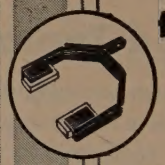
Use SILVER GRAPHALLOY*

For extraordinary electrical performance

GRAPHALLOY

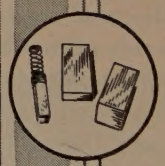
TRADE MARK REG. U. S. PAT. OFF.

THE SUPREME BRUSH AND CONTACT MATERIAL



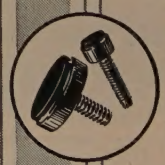
for BRUSHES

- **for high current density**
- **minimum wear**
- **low contact drop**
- **low electrical noise**
- **self-lubrication**



for CONTACTS

- **for low resistance**
- **non-welding character**



*Graphalloy is a special silver-impregnated graphite

Accumulated design experience counts — call on us!

GRAPHITE METALLIZING CORPORATION

1001 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

260

260

260

260

260

260

260

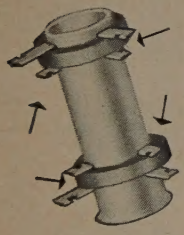
The Simpson volt-ohm-milliammeter that outsells all others combined.

N BROWNE ADVERTISING

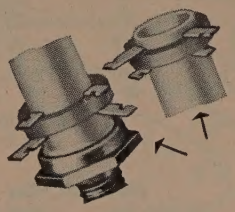
A Big Step Forward In Ceramic Coil Forms!

C.T.C.'s Nylon-Phenolic Terminal Retainers Mean More Advantages . . . *More Uses* . . . Than Ever Before

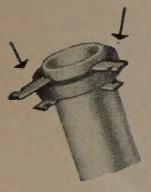
In making available ceramic coil forms with nylon-phenolic terminal retaining rings, C.T.C. now enables you to extend your use of these components considerably. The use of nylon-phenolic in no way impairs the moisture and fungus resistant qualities of the coil form assemblies. The nylon rings also provide many new benefits. For example:



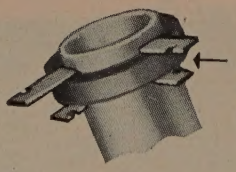
Excellent For Bifilar Windings. Four separate terminals, two on each nylon-phenolic ring, mean secure individual connections for each coil lead.



New Advantage For Single Pie Windings. Terminals can be located above or below winding, as required, to shorten wiring to circuit elements.



Soldering Spaces Doubled. Shape of terminals affords two soldering spaces on each, to segregate coil terminations from circuit wiring.



Terminals Held Securely In Place. Firmly cemented nylon-phenolic rings keep terminals in exact position. No sliding up or down.

In addition, the use of nylon-phenolic rings results in an increase in Q, giving improved performance over metallic rings. All materials and finishes meet exacting government specifications. Available with LST, LS5, LS6 coil forms.

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C.T.C.'s experienced component engineers are at your service — without cost — to help you secure exactly the *right* components. When standard parts are unsuitable they will design special units, working closely with you for economical, satisfactory results.

Call on the C.T.C. Consulting Service at any time. Just write to Cambridge Thermionic Corporation, 456 Concord Avenue, Cambridge 38, Massachusetts. West Coast stocks maintained by E. V. Roberts, 5014 Venice Blvd., Los Angeles and 988 Market Street, San Francisco, Cal.

custom or standard... the guaranteed components

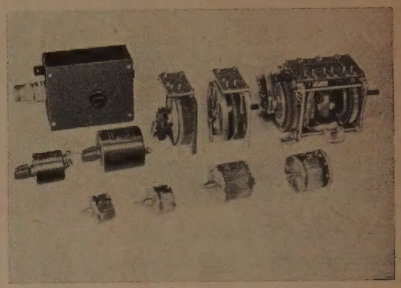
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 28A)

Variable Transformers

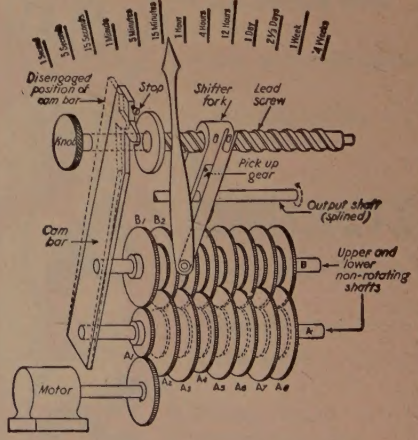
The Superior Electric Co., 83 Laurel St., Bristol, Conn., offers a line of POWERSTAT variable transformers for 400 cps and higher.



Since most of the higher frequency applications involve electrical equipment built to specific requirements, it is difficult to offer a complete line to fulfill every need. A variety of POWERSTAT variable transformers have been built to these specifications. Units are available in a multitude of voltage and current ratings in single and polyphase models.

Multispeed Instrument Drive

Gorrell & Gorrell, Haworth, N. J., have two new instrument drives designated the M-M and S-M units (minutes-to-a-month and seconds-to-a-month speed ranges). They utilize a single unit, motor, gear train, and speed selection mechanism. Applications are apparatus, instrument drives (chart, disc, etc.), chart movements, time and sequence controls.



The S-M unit provides 20 ounce-inch torque with output shaft rotation of 13 speeds, of 1, 5, 15 seconds, 1, 5, 15 minutes, 1, 4, 12 hours, 1, 2⅓ days, 1 and 4 weeks.

M-M unit provides 5 ounce-inch torque at the same speeds except of 1, 5, and 15 seconds. Both are for 115 volts 60 cps ac. Special assemblies for adjacent speed ratios can be had from 5:1 to 1:5, with individual differences as small as 59/61 available. Prices range from $65.00 for single units, to $19.75 for quantity orders.

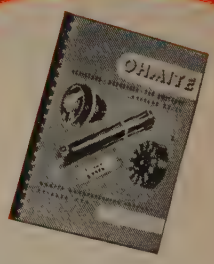
(Continued on page 60A)

OHMITE...

World Renowned for Dependability

To thousands of equipment manufacturers the world over—the name OHMITE has become synonymous with *QUALITY*. These manufacturers have put OHMITE resistance products through the most rigid of all tests—performance in the field—and these superior units have provided consistently dependable performance and long life under the most difficult operating conditions.

"Be Right with OHMITE" is more than just a slogan to these users. They know that when they specify OHMITE, they get the finest resistance equipment available—anywhere!



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Write for complete data: Our Bulletin I-D-2

Rutherford ELECTRONICS CO. 3707 S. ROBERTSON BLVD. CULVER CITY, CALIFORNIA

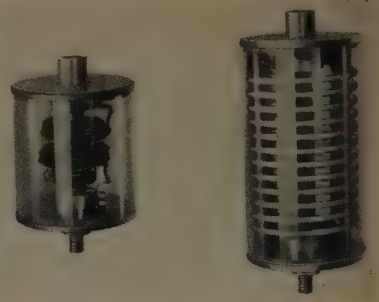
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 56A)

Loading Coils For Mobile Antennas

Two new base-loading coils, designed for use with any type mobile-whip antenna, have been announced by the **Mallard Manufacturing Co.,** 6025 N. Keystone Ave., Chicago 30, Ill.

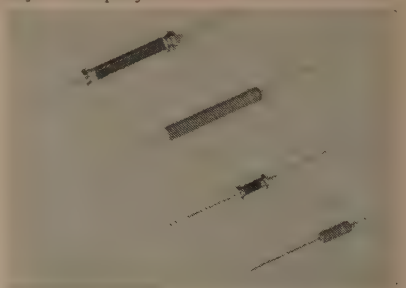


Available for 20 and 75 meter operation, the two new units are designed to fit all standard mounts and whips and, with the adaptor supplied, can be used with non-standard types. Both models are housed in a weather-proof $\frac{1}{8}$ inch thick plexiglass and have removable nylon end caps.

The Hi-Q 20 is wound with plated $\frac{1}{8}$ inch diameter solid copper wire. A flexible copper strap is provided which permits adjustment to exact inductance desired. The Hi-Q 75 features two pie-wound coils over a powdered iron core slug.

Deposited Carbon Resistors

A deposited carbon resistor, known as the "Carb-ohm" is being manufactured by the **Phaostron Co.,** 151 Pasadena Ave., South Pasadena, Calif. For high frequency applications, where high values of resistance are needed, or power dissipations up to 2 watts are required, the "Carb-ohms" may be employed.



These resistors are available hermitically sealed in glass, or clad in a humidity-impervious casing, which provides stability over time and freedom from variations due to climatic changes. "Carb-ohms" are available in a variety of mountings; the axial lead, pictured above, as well as a threaded stud or a tapped hole terminal. Wattage ratings range from $\frac{1}{3}$ to 2 watts with a resistance range of 20 ohms to 200 megohms.

The "Carb-ohm" is manufactured under license arrangements with Western Electric Co., Inc.

An illustrated brochure and complete information are available upon request.

(Continued on page 62A)

AEROVOX capacitors

★ Aerovox Application Engineering is yours for the asking. It means the RIGHT capacitor in the RIGHT circuitry for the RIGHT operating conditions. All adding up to Aerovox "performance insured" capacitors.

THE HOME OF CAPACITOR CRAFTSMANSHIP

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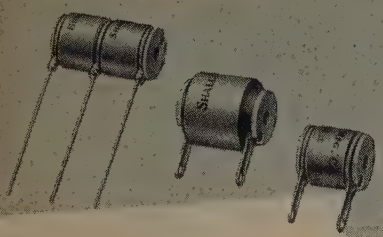
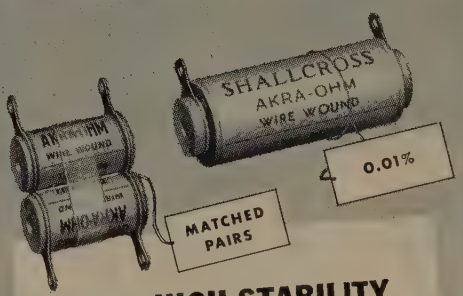


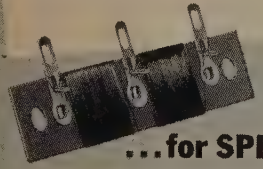
...for JAN EQUIPMENT

Shallcross is in constant touch with the latest military precision resistor requirements. The present line includes 13 types designed for JAN characteristic "B" and 4 types for characteristic "A".

...for MINIATURIZATION PROGRAMS

For years, Shallcross has led the way in the production of truly dependable close-tolerance, high-stability resistors in miniature sizes. Standard and hermetically sealed types are available.





...for SPECIAL ASSEMBLIES

Shallcross regularly produces hundreds of special precision resistor types including precision power resistors, resistors with axial or radial leads and multi-unit strip resistors (illustrated) with either inductive or non-inductive windings.

...for HIGH-STABILITY APPLICATIONS

Many Shallcross Akra-Ohm resistors are available with guaranteed tolerance to 0.01% and stability to 0.003%. Matched pairs and sets are supplied to close tolerances.

SHALLCROSS

SHALLCROSS MANUFACTURING COMPANY

COLLINGDALE, PA.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 60A)

Reversing Drum Switch

Announcement is made by **Allen-Bradley Co.,** 114 W. Greenfield Ave., Milwaukee 4, Wis., of a compact new reversing drum switch—Bulletin 350 Style A, suitable for a wide variety of mounting arrangements for small workshops and industrial services.

The Bulletin 350 Style A drum switch is the equivalent of a three pole double throw switch. It is small, simply designed, for machine and equipment requiring an economical across-the-line starting, and reversing switch for ac and dc motors rated at two horsepower or less.

Housing of the new unit is bakelite and contains eight fixed contacts, a moving contact assembly, handle-coverplate assembly, and mounting screws. Contacts are cadmium silver alloy, eliminating maintenance. Wide flexibility in mounting is provided.

Magnetic DC Power Supply Regulator

General Magnetics, Inc., 135 Bloomfield Ave., Bloomfield, N. J., has developed a new klystron dc power supply voltage regulator. There are no vacuum tubes, it has an all-magnetic amplifier-type circuit. This regulator maintains power supply output at 18,000 V dc for load current variations from zero to 100 ma, and line voltage variations from 105 to 135 V ac. Regulation accuracy is ±1 per cent. Time delay approximately 0.1 second. The unit may be easily and quickly modified for power supplies of any output rating.

(Continued on page 103A)

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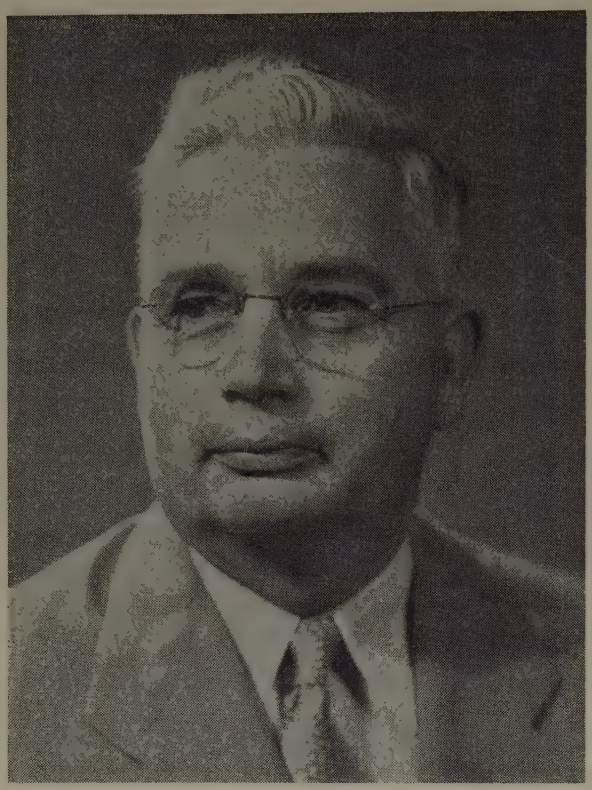


Clyde L. Farrar

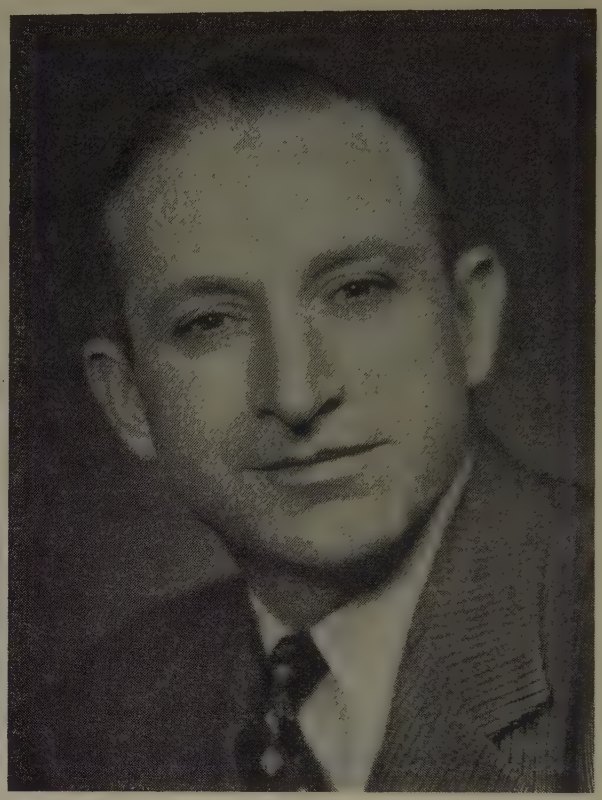
Chairman, Oklahoma City Section

Clyde L. Farrar, Chairman of the Oklahoma City Section, was born in Klamath Falls, Ore., in 1896, and received the B.S. degree in electrical engineering and the E. E. degree from the University of Colorado, in 1921, and 1926, respectively. From 1923 to 1929, he was associated with the University of Idaho as assistant professor of electrical engineering in charge of communication, and from 1929 to 1932 he was an associate professor and the technical director of Radio Station KUOA, at the University of Arkansas.

Mr. Farrar has been a member of the faculty of the University of Oklahoma since 1932, in the capacity of associate professor and professor of electrical engineering, and is, at present, the chairman of the School of Electrical Engineering, University of Oklahoma. He has also been the technical director for radio station WNAD and WNAD-FM, University of Oklahoma, from 1932 to the present. Mr. Farrar has been a contributor to various engineering and electronic publications. At one time he was the research supervisor for research projects at the Wright-Patterson Air Force Base.

A Fellow of the American Institute of Electrical Engineers, Mr. Farrar is a member of various professional and honorary societies including, the American Society for Engineering Education, the Oklahoma Society of Professional Engineers, Sigma Xi, Sigma Tau, and Eta Kappa Nu.

Mr. Farrar became a Member of the IRE in 1945, and was elected as Chairman of the newly formed IRE Oklahoma City Section, in October, succeeding Acting Chairman O. A. Nash.



Daniel Silverman

Chairman, Tulsa Section

Daniel Silverman, Chairman of the Tulsa Section, received his B.S. degree in electrical engineering in 1927, at the University of California, where he accepted an assistantship for one year after his graduation. He then attended the Massachusetts Institute of Technology, and received the M.S. and D.Sc. degrees in electrical engineering and physics in 1929, and 1930, respectively. The following four years Dr. Silverman spent with the Westinghouse Company working in various fields such as arcs, gaseous conduction devices, and ignitrons. The next 2 years he worked with the Arma Corporation in Brooklyn in the research, development, and design of navigation and fire-control instruments.

After a year of teaching mechanical engineering at the University of California, from 1936 to 1937, Dr. Silverman was offered a position with the Stanolind Oil and Gas Company in their research department. Since 1941 he has been in charge of the geophysical research work of the Stanolind Company and at present holds the position of Exploration Research Director.

Dr. Silverman is a member of the Society of Exploration Geophysicists, the American Association of Petroleum Geologists, the Seismological Society of America, the American Geophysical Union, the American Institute of Mining and Metallurgical Engineers, the Acoustical Society of America, and the American Physical Society.

An Associate Member of the IRE in 1942, Dr. Silverman became a Senior Member in 1951. He is the first Chairman of the newly formed IRE Tulsa Section.

Concerning Research, Development, and Engineering

J. F. Byrne

Communications and electronic engineering does not end with a theoretically correct (and even highly ingenious) design of needed equipment. Unless the operational aspects, which particularly include reliability under adverse conditions, are equally considered, the engineer's task is only half done.

The following guest editorial is therefore especially timely in a troubled period like the present. It was written by a Fellow of the Institute, who is Director of Engineering in the Communications and Electronics Division of Motorola Inc.

Today economy and dependability of apparatus are particularly at a premium. Hence the following thoughts are especially directed to the attention of the readers of these Proceedings.—*The Editor.*

The rapid advances in the state of the electronics art, particularly in the last decade, are achievements of which we as electronic engineers and physicists are justifiably proud. Even a casual review of the Proceedings of the I.R.E., through this period, will emphasize the progress that has been made. Many trails have been blazed through the wilderness of the unknown. Men, spurred on by critical world conditions and the national consciousness that development and research *must* continue, are almost daily finding new areas of exploration.

Are we sufficiently aware that the fundamental benefits of exploration of the wilderness are not achieved until the highways are paved? Trail blazing, like research and advanced development, is a glamorous activity; paving highways, the reduction of ideas to everyday engineering practice, is plain hard work.

Do we really take sufficient interest in the proper, reliable *application* of new principles? Do we recognize the tremendous importance of engineering work which leads to a truly reliable vacuum tube or perhaps a radar? Are we aware of the fact that to some extent we have built a house of cards that may fall apart at the very time we need it most?

We in the IRE should recognize and point out in all ways at our command the importance of thoroughly engineered contributions as well as the discovery of new areas of scientific exploration. Achievements in production design, quality control, and dependability of either complex systems or a commonplace component are essential to our success. A redoubled effort along these lines is long overdue—let us resolve to encourage the improvement of old highways as well as the blazing of new trails.

Management Aspects of Electronic Systems Engineering*

RALPH I. COLE†, SENIOR MEMBER, IRE

Summary—This paper cites that in the rapid growth of electronics engineering, management has not always appreciated the full magnitude of the "systems engineering" problem. In setting forth what alert management should attempt to accomplish, the systems engineering influence in research and development is discussed in some detail. In this regard particularly is it significant that more care must be given to the planning of features that make for simpler maintenance in large complicated systems. Installation problems are dealt with briefly and particular emphasis is given to the noise reduction problem within the systems in order that the best optimum *repeatable* results are obtained. Finally, the engineering management phases are treated from the standpoint of management assuming greater responsibility to see that increased engineering emphasis is given to proper maintenance of installed systems.

I. Introduction

THAT "SYSTEMS ENGINEERING" is a challenging field for electronics engineers is hardly open to question. That management can and should contribute greatly to the success of "systems" thinking and operations is not always appreciated. Furthermore, the rapid growth of the electronics field has, in general, caught ever-busy engineering management ill prepared aggressively to plan for the future, and as a result they have been chiefly engaged in solving today's problem today. It is becoming increasingly apparent that the specialization of "engineering management" is essential if efficient utilization is to be made of our nation's manpower and facilities. This is doubly important in the field of electronics systems engineering.

II. Systems Engineering Influence in Research and Development

A. Previous mention of the fact that management should provide for *future planning* is apparent everywhere in the electronic systems field. In general, "planning" may be said to be the cornerstone of "systems" effort. There is rarely any disagreement that upon the soundness of advanced planning will depend in large measure the degree of success, but there is a wide difference of opinion as to how much of this effort should be programmed in advance and by whom. The arising of the need for new electronics systems has stressed the urgency of this problem since, in general, "systems" have cut across many previously considered separate specialties which previously were quite snug and complete within themselves.

B. The need for providing for future growth possibilities of electronic systems stresses the fact that separate component and equipment developments must be closely co-ordinated in order to produce modern up-to-date systems. Furthermore, obsolescence of systems can be avoided only by tying together evolutionary equipment specifications with the encompassing systems ones. These problems point up the fact that the systems engineering influence has produced a need for greater co-ordination than ever before. Likewise, increased activity in deriving new "systems standards" mutually acceptable to large groups of engineers is becoming of increased importance in the entire research and development field. It is causing a revision of many of the concepts previously considered sacred.

C. It is only natural that the tying together of many separate electronic equipments to form systems would markedly reflect in all phases of research and development. Particularly is this true when considering the problem of evaluating the success of the research and development effort. While testing of the individual equipments making up a system provide in some measure an indication of the over-all results to be expected, management should not assume that "systems" merely fit together by assemblage of individual components and equipments. A *comprehensive* systems engineering test program drawn up with greatest care is an absolute must for performance evaluation. The details of this program have previously been discussed in a separate paper.[1]

D. It has become increasingly apparent that one of the greatest influences that systems engineering will have on research and development programs will be a realization of a need for review of the entire "maintenance problem." No longer is it possible to consider that the maintenance practices previously evolved for simpler equipments will suffice for the electronic systems now under research and development. As is usually the case, necessity is the mother of invention, and with encouragement on the part of management the research and development of new maintenance techniques applicable to systems can and should be stressed. In particular, some of the newer maintenance practices in the evolutionary stage are as follows:

(1) Provision for "test points" at various places within the system to enable proper reading of all types of control voltages.

(2) "Supervisory" control from a remote point over the operations of the system including automatic measuring devices and quality evaluation. By way of example, provision can now be provided for judgment of the approximate number of hours of life left in certain elements of a system prior to the need for replacement of any element. Also possible is the provision of remote reading and recording of control parameters to the end that reliability can be judged.

(3) Individual segmentation of circuit elements to permit replacement as a unit. This enables subsequent renewal by an entire separate, similar element without the need to await repair of the original. In some designs, it may even be possible for clever engineering to so reduce the cost of manufacture of the element as to enable discarding rather than repair, in which case the technical maintenance problem is transferred back to the factory.

E. While one often hears the term "industrial designer" (as, for instance, in the automotive field), his potential influence in the research and development of electronic systems is not always realized. In one particular field, however, namely, that of radio and television broadcasting, the industrial designer entering the electronic systems field has greatly simplified control and at the same time made for a more pleasing appearance of the elements making up the complete installation. What has been achieved there is undoubtedly possible in other fields, and the electronic engineer who is not familiar with the industrial engineering practices should, before undertaking systems development, be made conversant with what can be achieved by this type of designer.

III. Engineering Problems Concerning Systems Installation and Initial Operation

A. It has previously been pointed out that "electronic systems" must be subjected to a careful evaluation program during the research and development stages. During this period, performance limits will be established and the proof of the degree of success will be the *repeatibility* of this data under actual operating conditions after the initial installation.

B. The performance of electronic systems irrespective of the exact nature or type is, in general, a function of the noise level either internally generated or induced within the system from outside radiation. In either case, one finds that the noise level at the output terminals may prove unexpectedly large if the planners have not foreseen the problems and have recognized the meticulous detail which must be followed in electronics installation work. Management should appraise these problems as having a distinct bearing upon operating success, and should in this regard be guided by the following:

(1) Keep all lengths of leads as short as possible.

(2) Design all transfer circuits to be of the lowest possible impedance since by so doing the noise pickup factor is greatly reduced.

(3) Plan for the suppression of direct radiation pickup insofar as possible by such methods as shielding and by employing as great a physical separation from the disturbing element as is possible.

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† 3151st Electronics Group, Griffiss Air Force Base, Rome, N. Y.

[1] R. I. Cole, "Management's role in research and development of electronic systems," PROC. I.R.E. vol. 38, pp. 1252–1253; November, 1950.

(4) Insure that where interconnections between equipments of a system are required that the connecting "paths" be examined, particularly when it is planned that many wires are to be run in the same cable without shielding.

(5) Insure that provision is made for adequate *grounding* of all elements of the system in order to reduce circulating currents and hence to reduce the noise level.

(6) Make adequate allowances in the planning to provide for filtering of expected noise and to provide for *extra filter elements* so that they may be on hand when final testing is to be made.

C. No discussions of systems installation and, in particular, electronic systems installation would be complete without mention of the fact that provision must be made for special operator and technician training to carry on the various specialized functions. Often this action requires management to set up special training schools as well as insuring the preparation of special handbooks covering installation practices which may be placed at the disposal of the operator and technician.

IV. Engineering Management of Installed Systems

A. Having placed an electronic system into operation, the problem of how to keep all elements functioning properly day after day now assumes greatest importance. Engineering managements must not relax in their diligence of frequently re-examining the problem of what could be called "maintenance engineering." This specialty is one of the most neglected fields and strong measures must be taken to insure greatly improved operation at lowest possible cost. The following are a few of the many problems which management should stress:

(1) Preparation of adequate systems maintenance manuals to insure that operator and maintenance personnel can understand the systems operation and can spot trouble as it develops.

(2) Establishing a system of routine preventive maintenance to insure that minimum outages will result in any given period.

(3) Establishment of a reserve supply of components which are most likely to fail during given periods of operation, often based upon an interval of time of one year.

(4) Establishment of daily or hourly log sheets to indicate performance being achieved, and thereby being able to compare at any time with that achieved previously.

V. Conclusions

The guide lines and criteria set forth herein are but a few of the many that should be used by engineering management in evaluating electronic systems engineering effort. It is apparent that there is room for tremendous growth in this particular field. Engineering management must be prepared to solve ever more complicated tasks if the great strides promised by new inventions are to become a reality and consequently be incorporated into electronic systems.

High-Frequency Gas-Discharge Breakdown*

SANBORN C. BROWN†

This paper has been secured by the Tutorial Papers Subcommittee of the IRE Committee on Education as a part of a planned program of publication of valuable tutorial material. It is here presented with the approval of that Subcommittee.—*The Editor.*

Summary—**A phenomenological description of high-frequency gas-discharge breakdown is given, describing the similarities and differences between these discharges and the more familiar dc type. High-frequency discharge breakdown is controlled by the process of electron diffusion and, besides the theory of its behavior, the physical limitations of tube size, gas pressure, and frequency for this type of breakdown are given. The particular case of hydrogen is cited. The effects of superimposing a small dc field and a magnetic field on the ac field are also discussed.**

Introduction

KNOWLEDGE of the breakdown of a gas discharge under the action of a high-frequency field has greatly increased in the last few years. The present paper is written to describe the similarities and differences between these discharges and the more familiar dc type of breakdown, discussing the physical phenomena that occur, and showing the type of information that may be obtained from these relatively simple types of breakdown.

In a high-frequency gas-discharge breakdown, the primary ionization due to the electron motion is the only production phenomenon which controls the breakdown. For this reason, high-frequency studies are much simpler than the dc type of breakdown which must always have a source of electrons present (often supplied by secondary electron effects) to make up for the electrons which are continuously swept out by the field. If one calculates the maximum kinetic energy in the oscillatory motion of an electron at the minimum field intensities for breakdown experimentally determined, one finds that this energy corresponds to about 10^{-3} electron volt. Therefore, it is obvious that the energy of oscillation is insufficient to account for breakdown.

A free electron in a vacuum under the action of an alternating field oscillates with its velocity 90 degrees out of phase with the field. It thus takes no power, on the average, from the applied field. The electrons can gain energy from the field only by suffering collisions with the gas atoms, and they do so by having their ordered oscillatory motion changed to random motion on collision. The electrons gain random energy on each collision until they are able to make inelastic (exciting or ionizing) collisions with gas atoms. The fact that the electron can continue to gain energy in the field, on

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the average, despite the fact that the field changes sign, can be seen by showing that the energy absorbed is proportional to the square of the electric field and, hence, independent of its sign. The rate of gain of energy of the electron from the electric field E_{rms} is $P=eEv$, where e is the electronic charge and v is the average drift velocity resulting from the applied electric field.

If the electrons are acted on by an electric field $E=E_0e^{j\omega t}$, oscillating with a radian frequency ω, in the presence of a gas in which collisions act as a viscous damping force, Lorentz[1] showed that the equation of motion may be written

$$m(dv/dt) + (m\nu_c)v = -eE_0e^{j\omega t}. \quad (1)$$

The collision frequency ν_c is the reciprocal of the mean free time between collisions and is considered to be constant. The electron velocity determined from this equation of motion can be written

$$v = -eE_0e^{j\omega t}/(j\omega m + m\nu_c). \quad (2)$$

The average drift velocity of an electron is proportional to the electric field in which it travels and the proportionality constant is called the mobility μ. Thus $v=-\mu E$, which may be written in the form of an ac mobility.

$$\mu = e/m(j\omega + \nu_c). \quad (3)$$

This expression can be compared with the case of dc electric fields where $\omega=0$, or with the case of high-pressure discharges where the collision frequency is much larger than the radian frequency of an oscillating electric field, in which one of the standard expressions for the mobility of the form $\mu=e/m\nu_c$.

The current density of n electrons per unit volume is $J=-nev$ where the velocity is given by (2). Separating the real and imaginary parts of the current, we may write E for E_{rms}, and

$$J = \frac{ne^2E}{m\omega}\frac{\nu_c/\omega}{(\nu_c/\omega)^2+1} - j\frac{ne^2E}{m\omega}\frac{1}{(\nu_c/\omega)^2+1}. \quad (4)$$

The rate of energy gain of the electrons from the field is the real power going into the gas per unit volume,

$$P = J_rE = (ne^2E^2/m\nu_c)[\nu_c^2/(\nu_c^2+\omega^2)]. \quad (5)$$

It is convenient to write the electric field in terms of an effective field which would produce the same energy transfer as a dc field

$$E_e^2 = E^2[\nu_c^2/(\nu_c^2+\omega^2)], \quad (6)$$

so that the rate of energy gain of the electrons from the field is

$$P = ne^2E_e^2/m\nu_c. \quad (7)$$

Thus we see that the rate of energy gain of the electrons in the field is proportional to the square of the electric field, and therefore in a manner independent of the sign of that field.

Diffusion of Electrons

A gas-discharge breakdown occurs when the gain in electron density due to the ionization of the gas becomes equal to the loss of electrons. In a dc discharge, the electron loss is due primarily to the mobility motion caused by the steady electric field. In the ac case, the electrons are not thus swept from the discharge and their loss can be due to such phenomena as diffusion, recombination, and attachment. Under all experimental conditions so far studied of high-frequency breakdown, the loss has been due entirely to diffusion.

Diffusion occurs whenever a particle concentration gradient exists. The total flow of particles out of a volume of high concentration may be written from ordinary kinetic theory considerations[2] as

$$\Gamma = -D\nabla n, \quad (8)$$

where D is the diffusion coefficient for electrons, n the electron density, and Γ the electron current density in electrons per second per unit area. The diffusion coefficient is proportional to the average velocity of the electrons and in terms of the mean free path, l, may be written as $D=lv/3$.

We will develop the breakdown conditions for a region bounded by walls which absorb electrons. A radioactive source near the discharge tube provides a small amount of ionization S in the tube. A detailed study of the build-up of the discharge is obtained from considering the continuity equation for electrons

$$\partial n/\partial t = \nu_i n + S - \nabla\cdot\Gamma \quad (9)$$

or in terms of (8)

$$\partial n/\partial t = D\nabla^2 n + \nu_i n + S. \quad (10)$$

In this equation the term $D\nabla^2 n$ describes the loss of electrons by diffusion. The term $\nu_i n$ is the rate of gain of electrons by ionization and S is the rate at which electrons are produced by an external source. For the case of infinite parallel plates

$$\partial n/\partial t = D(\partial^2 n/\partial x^2) + \nu_i n + S. \quad (11)$$

Assuming that the approach to breakdown is so slow in time that $\partial n/\partial t$ may be neglected,

$$-S = D(\partial^2 n/\partial x^2) + \nu_i n. \quad (12)$$

This is a characteristic value problem which may be solved under the conditions that S is uniform throughout the cavity and that the boundary condition on the electron density is zero at the walls. The solution of this equation tells us that the electron density before breakdown, at any distance x from the median plane between

[1] H. A. Lorentz, "The Theory of Electrons," Leipzig, Germany; 1909.

[2] E. H. Kennard, "Kinetic Theory of Gases," p. 188, McGraw-Hill Book Co., Inc., New York, N. Y.; 1938.

parallel plates of separation L, may be written

$$n = (4S/\pi) \cos (\pi x/L)/[D(\pi/L)^2 - \nu_i]. \quad (13)$$

Breakdown can be defined by the condition that the electron density goes to infinity, which occurs when $\nu_i = D(\pi/L)^2$.

If we write $\nu_i/D = (\pi/L)^2 = 1/\Lambda^2$, for parallel plates, the quantity Λ is known as the characteristic diffusion length and is very useful in describing the shape of the gas container when discussing diffusion problems. One other example of a very useful boundary condition is the case of a cylinder of height h and radius r, with flat ends. This geometry leads to the relation that $1/\Lambda^2 = (\pi/h)^2 + (2.4/r)^2$, where the diffusion to the end plates is given by the first term on the right and the second term describes the diffusion to the cylindrical walls.

Ionization Coefficients

Gas-discharge phenomena under the action of dc fields are often described in terms of Townsend ionization coefficients. If one considers that electrons in a dc field create α new electrons in a path one centimeter long in the field direction, the increase of electrons, dn, produced by n electrons in a distance dx will be $dn = \alpha n\, dx$, and $n = n_0 e^{\alpha x}$ where n_0 is the initial electron concentration. The quantity α is called the first Townsend coefficient. This first Townsend coefficient may also be written as the ionization produced by an electron falling through a potential difference of one volt rather than travelling one centimeter. This coefficient is given the symbol η and is related to α by $\eta = \alpha/E$.

These Townsend first ionization coefficients may be given in terms of an "ionization" collision frequency. Since α is the number of electrons produced by the collisions of the primary electrons travelling one centimeter, one can write $\alpha = \nu_i/v$, where ν_i is the frequency of ionization and v is the average drift velocity of the electrons in the field. The average drift velocity $v = |\mu E|$, and one may write $\alpha = \nu_i/\mu E$ or

$$\eta = \nu_i/\mu E^2. \quad (14)$$

By analogy with the first Townsend coefficient for dc ionization where the electron loss is controlled by mobility, we may define a coefficient for high-frequency discharges[3] where the loss is by diffusion as:

$$\zeta = \nu_i/DE^2. \quad (15)$$

From our previous discussion of diffusion we saw that at breakdown $\nu_i/D = 1/\Lambda^2$. Thus we may measure the ac ionization coefficient by measuring the breakdown field in tubes of known size since $\zeta = 1/\Lambda^2 E^2$. Measurements of ζ as a function of E/p, the ratio of the rms electric field, and the pressure for various gases are shown in Fig. 1.

[3] M. A. Herlin and S. C. Brown, "Breakdown of a gas at microwave frequencies," *Phys. Rev.*, vol. 74, p. 291; August, 1948.

There is a very close physical relation between the ac and the dc ionization coefficients. If one divides (14) by (15), there results the relation $\eta/\zeta = D/\mu$. Townsend showed that the ratio of D/μ was a measure of the average energy of the electrons[4] and determined this average energy as a function of E/p, experimentally.

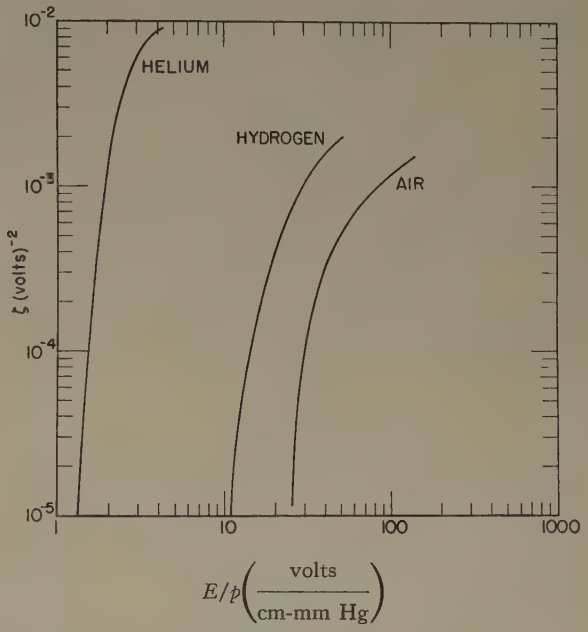

Fig. 1—AC ionization coefficient for helium, hydrogen, and air.

Thus, in principle, one can determine η from ζ or vice versa from these Townsend-like measurements. There is difficulty in carrying this out exactly, however, because the actual values depend on how the averaging of the energy is carried out. Since the electron energy-distribution functions are different for the ac and the dc cases, one might expect mathematical complications to arise if this were tried in actual cases. For the one case of hydrogen gas, where considerable simplifications are possible in the mathematics, it has been shown[5] that the dc Townsend coefficient can be determined from the ac ionization coefficient.

High-Frequency Breakdown

Typical of the behavior of the breakdown field at high frequency with changes in gas pressure are the curves shown in Fig. 2. At first sight these curves look similar to corresponding data taken with dc fields, that is, as the pressure is decreased the breakdown field first decreases and then increases again at low pressures. In the low-pressure region, the rising breakdown field with decreasing pressure in high-frequency discharges corresponds to the increasing loss of efficiency in the transfer of energy from the field to the electrons. We saw in the introduction that the electron only gained energy insofar as it made collisions with the gas atoms

[4] J. S. Townsend, "Electricity in Gases," Clarendon Press, Oxford, England, p. 166; 1915.

[5] L. J. Varnerin, Jr. and S. C. Brown, "Microwave determination of average electron energies and the first Townsend coefficient in hydrogen," *Phys. Rev.*, vol. 79, p. 946; September, 1950.

and that between collisions it oscillated out of phase with the field and hence gained no energy. Thus, as the pressure is reduced, one must increase the field to make up for the loss of efficiency by just the factor of the effective field given in (6). In the high-pressure region,

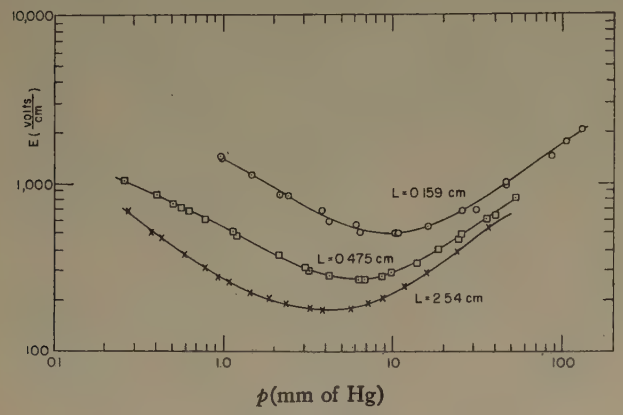

Fig. 2—Typical breakdown curves for hydrogen at a frequency of 3,000 mc.

the reason for the rising breakdown field with increasing pressure in high-frequency discharges is the same as in the dc case. As the pressure increases, the electron mean free path decreases, and the energy per mean free path decreases. Since to cause ionization the electron must gain energy corresponding to the ionization potential, more and more electric field must be applied to do this as the pressure increases. The minimum corresponds essentially to the point where the frequency of collision between electrons and gas atoms is equal to the frequency of the applied rf field. Thus, at low pressure where the electron makes many oscillations per collision, its behavior is governed by strictly ac considerations. At high pressure, where the electrons make many collisions per oscillation, their behavior is the same as in a dc discharge.

The remarkable feature of the breakdown curves, for those used to dc phenomena, is the fact that the greater the electrode spacing, the easier it becomes to cause a breakdown. This, of course, is a necessary result of the breakdown condition of the balance between energy gained from the field and electron loss by diffusion. As the electrode spacing becomes less, the diffusion loss becomes greater; therefore, the field must increase to make up for the increased loss.

Curves of gas-discharge breakdown as a function of pressure are often plotted in dc work as Paschen curves in which, for a particular gas, the breakdown voltage V is found to be a function of pd independent of the magnitude of the electrode spacing d. The same type of quantities may be introduced in the high-frequency case, where for the breakdown voltage we write $E\Lambda$, the field times the diffusion length, and for pd we use $p\Lambda$. In the case of high-frequency phenomena we have one more variable than for the dc case, namely, the frequency, and this may be introduced as the variable $p\lambda$ where λ is the wavelength of the applied field. In terms of these three variables, all high-frequency breakdown data may be put on a three-dimensional surface. This is illustrated for the case of hydrogen in Fig. 3. In this kind of a plot, breakdown data taken for a given size tube at constant applied frequency as that of Fig. 2,

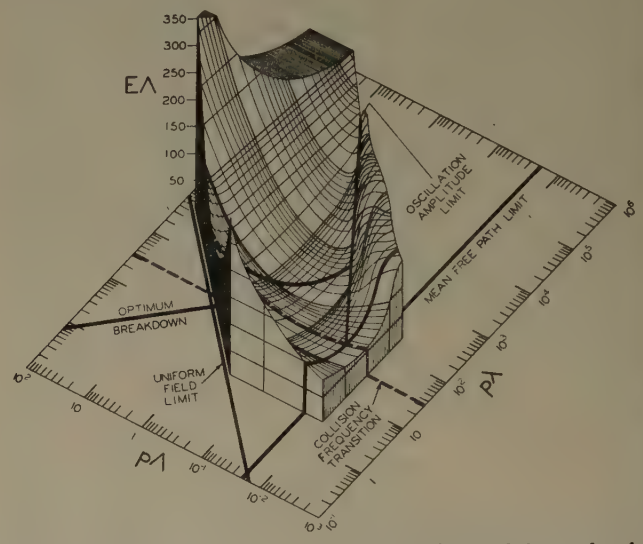

Fig. 3—A surface constructed from the experimental determinations indicated in Fig. 2, correlating the breakdown voltage measurements in terms of variables derived from dimensional analysis.

fall on lines at 45 degrees in the $p\Lambda - p\lambda$ plane. All the higher-pressure data taken above the minimum breakdown field correspond to the case of an electron making many collisions per oscillation. In this case the frequency of the applied field makes no difference, that is, the data are independent of the variable $p\lambda$ and all the $E\Lambda$ versus $p\Lambda$ curves have the same shape, corresponding to the Paschen Law curves for dc breakdown. This is shown in Fig. 4.

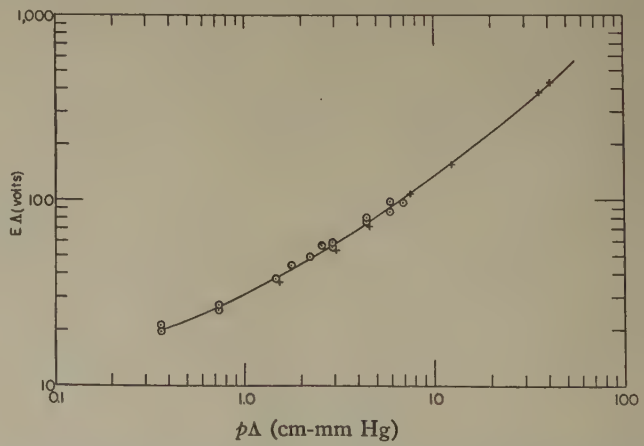

Fig. 4—High-pressure ac breakdown data showing similarity to dc Paschen law when electron makes many collisions per oscillation. Crosses are data at 10 cm wavelength (7) and circles are wavelengths of 16,700; 10,600; 8,050; 4,740; 460; and 389 cm (10).

Breakdown Theory

To derive a more quantitative description of the breakdown behavior and avoid mathematical complexity, one must choose a gas in which simplifying assumptions are most likely to apply. The two most important of these assumptions are, first, that the frequency of

collision be constant in energy, an assumption we have already used in (1), and, second, that all inelastic collisions be ionizing, that is, that there be no excitation. There turns out to be no such gas in nature, but it is possible to make such a gas by adding small amounts of mercury vapor to helium. Let us coin a name of "Heg" for this gas. The helium gas by itself has the property, in the region of electron energy in which breakdown occurs, of behaving such that ν_c=constant. Helium has a metastable level at 19.8 volts since transitions from this level to the ground state by radiation are forbidden. Since the metastable states have mean lives of the order of thousands of microseconds, practically every helium atom which reaches an energy of 19.8 volts will collide with a mercury atom and lose its energy by ionizing the mercury. Therefore, each inelastic collision will produce an ionization and the effective ionization potential will be $u_i=19.8$ volts.

Having thus found a gas to which we can apply a simple theory, let us first consider what happens at high pressure. Here the power which goes into the electrons from the electric field is dissipated in elastic collisions between the electrons and the gas molecules. This region corresponds to the lowest values of E/p measured experimentally. The data on either the Townsend first ionization coefficient or the ac ionization coefficient, such as in Fig. 1, show that here E/p is nearly constant for a wide variation of these coefficients and is equal in Heg to 1 rms volt/cm/mm Hg. Thus, for an Heg discharge, in which nearly all the loss goes into nonionizing collisions, the field and pressure are related by the equation $E=p$. It can be seen that the high-pressure breakdown measurements tend to approach this line. This is shown in Fig. 5.

In the low-pressure region, the electrons make many oscillations per collision and the breakdown field may be determined by equating the number of oscillations to ionize to the number of collisions to diffuse out of the tube. Since all inelastic collisions are ionizing ones, all the input power (which is the rate of transfer of energy) goes into ionization, this is to say that the power is the frequency of ionizing collisions, ν_i, times the energy to ionize a gas atom, eu_i. Thus we may write from (7),

$$\nu_i = P/eu_i = eE_e^2/mu_i\nu_c. \tag{16}$$

Since we are discussing the low-pressure region, we may assume that $\omega^2 \gg \nu_c^2$ in (6) for E_e^2. In the diffusion section we found that $\nu_i=D/\Lambda^2$ and that $D=lv/3$. This leads to a relation for the frequency of ionization of the form $\nu_i=lv/3\Lambda^2$. If we multiply numerator and denominator of this expression for ν_i by the velocity and combine with (16) we obtain

$$\nu_i = v^2/3\Lambda^2\nu_c = eE^2\nu_c/u_im\omega^2. \tag{17}$$

We solve this expression for the electric field. For ω we may write $2\pi c/\lambda$, where c is the velocity of light. The electron energy is related to the velocity by the equation $eu=mv^2/2$. Combining these, we obtain

$$E = 2\pi c\sqrt{2uu_i/3}/\Lambda\lambda\nu_c. \tag{18}$$

The collision frequency ν_c has been measured for many gases and the results have been summarized by Brode.[6] Brode gives his results in terms of the probability of collision P_c, which may be defined as $1/pl$. The relation between the probability of collision and the frequency of collision is $\nu_c=pvP_c$, since elementary considerations show that ν_c may be written as v/l. From Brode's data we find that $\nu_c=2.37\times10^9p$. For Heg the ionization potential $u_i=19.8$ volts; since we are assuming a very low pressure where all the power goes into ionization, the average energy u also equals 19.8 volts. Calculating the electric field under these approximations leads to a relation $E=1284/p\Lambda\lambda$. Calculating the electric field from this relation for the two different size cavities, for which data are given in Fig. 5, shows that the experimental values do approach these theoretical lines at very low pressures.

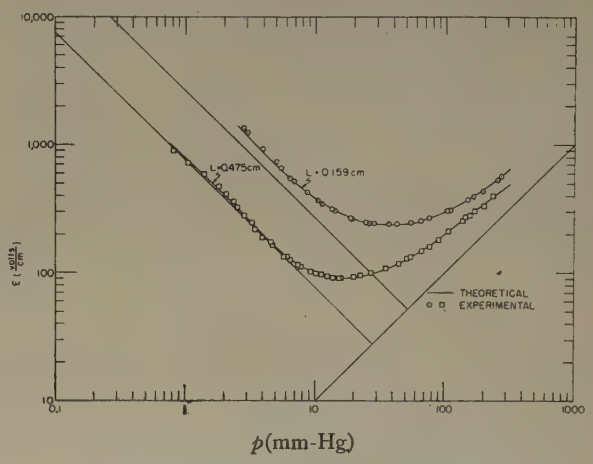

Fig. 5—Experimental breakdown electric fields compared with a simplified theory.

In this paper we have treated the breakdown problem in a qualitative manner, discussing the behavior of an average electron. This gives us less accurate agreement in detail than a more rigorous treatment, but allows us to discuss the mechanisms in a correct and more easily understood fashion. An accurate description of the breakdown phenomena can be given theoretically only by taking into account the electron energy distribution. The electron energy-distribution function may be determined by setting up the electron continuity equation, accounting for production and loss of electrons by ionization and diffusion, and expressing the results in terms of the high-frequency ionization coefficient ζ. The precision with which such a treatment predicts the experimental observations gives us confidence in the validity of the approach, but the mathematical complexity of this type of theory largely obscures a clear picture of the mechanisms involved. For

[6] R. B. Brode, "The quantitative study of the collisions of elections with atoms," *Rev. Mod. Phys.*, vol. 5, p. 257, October, 1933.

the more rigorous treatment, the reader is referred to the original papers on the subject.[3,7]

The Limits of Diffusion-Controlled Breakdown

Certain basic assumptions have been made in the calculations of breakdown as a balance between the ionization rate and the loss of electrons by diffusion. Let us examine the limits of experimental parameters beyond which diffusion is no longer the controlling phenomenon. These limits can be discussed in terms of the variables $p\Lambda$ and $p\lambda$, and we will choose the case of hydrogen since more quantitative work has been done with this gas than any other.

At low frequencies the experimental measurements of breakdown are always taken in vessels whose dimensions are small compared to the wavelength of the exciting power. For this case, an assumption of uniform field between the electrodes is very good. At very-high frequencies there exists a limit to the size of the discharge tube consistent with the assumption of the diffusion theory that there be no region of zero electric field except at the walls of the tube. This can be written in terms of the size of the tube allowable to sustain a single loop of a standing wave of the electric field. The relation between the parallel plate separation L and the wavelength is that $\lambda/2=L$. Since in terms of the diffusion length $L=\pi\Lambda$, the Uniform Field Limit shown in Fig. 3 is calculated from

$$p\lambda = 2\pi(p\Lambda). \tag{19}$$

The diffusion theory will not apply where the electron mean free path becomes comparable to the tube size. In the limiting case, this can be expressed as the mean free path l being equal to the diffusion length Λ. We have seen that the probability of collision P_c is equal to $1/pl$. To plot this condition in Fig. 3, we write

$$p\Lambda = 1/P_c. \tag{20}$$

The value of P_c is not a constant, but depends upon the electron energy. Assuming that the average electron has an energy equal to one third of the ionization potential, the average electron energy would be 5 volts for hydrogen. Using Brode's measured value for the probability of collision in hydrogen for the average electron, $P_c=49$(cm-mm Hg)$^{-1}$. With this value, we obtain the horizontal line in Fig. 3 marked *mean free path limit.*

Within the limits of experimental conditions in which diffusion theory adequately explains the breakdown behavior, several different phenomena may occur. One of the important phenomenological changes is the transition from many collisions per oscillation of the electron to many oscillations per collision. This can be written as the condition that $\nu_c=\omega$, where ν_c, the collision frequency, is the ratio of the average velocity to the mean free path, and ω is the radian frequency of the applied field. From Brode's data, we can obtain the relation $\nu_c=5.93\times10^9p$. Putting this in terms of the proper variables, we obtain

$$p\lambda = 32. \tag{21}$$

This relation is plotted in Fig. 3 as the dotted line marked *collision frequency transition.*

We can calculate a line on the $p\Lambda-p\lambda$ plane corresponding to the minimum breakdown field for any given container size. At low pressure we have seen that the breakdown field approaches the condition given by (18). For hydrogen $\nu_c=5.93\times10^9p$, $u_i=15.4$ volts and we again consider $u=u_i$. This leads to a value of $E=400/\Lambda\lambda p$. The limiting value of E/p for the ionization coefficient in hydrogen is 8 volts/cm/mm Hg. Therefore at high pressures $E=8p$. Eliminating the field between these two equations will allow us to calculate the pressure at which breakdown will occur most easily. In terms of the variables of Fig. 3 this leads to the equation

$$p\lambda = 50/p\Lambda. \tag{22}$$

This relation is plotted in Fig. 3 as the line marked *optimum breakdown.*

When the amplitude of the electron oscillation[8] in the electric field is sufficiently high, the electrons can travel completely across the tube and collide with the walls on every half cycle. We have already seen that under the action of the field, an electron attains a velocity $v=eE/m\nu_c$. Putting in the sinusoidal variation of the field with time,

$$\begin{aligned} v &= -(eE_p/m\nu_c)\sin\omega t \\ x &= (eE_p/m\omega\nu_c)\cos\omega t, \end{aligned} \tag{23}$$

where E_p is the peak value of the field. The limiting case on the diffusion mechanism in which all of the electrons will hit the walls would be calculated by setting the oscillation amplitude equal to one half the electrode separation. Thus the oscillation amplitude becomes equal to $eE_p/m\omega\nu_c=L/2$. Substituting λ in terms of ω, v/l in place of ν_c, and $1/pP_c$ for l we obtain

$$p\lambda = (\pi mcvP_c/e)pL/(E_p/p). \tag{24}$$

From Brode's data again we use $vP_c=5.93\times10^9p$(cm-mm Hg)$^{-1}$, and putting in this numerical value with the parallel plate relation that $L=\pi\Lambda$, one has

$$p\lambda = 10^6p\Lambda/(E_p/p). \tag{25}$$

This equation can be solved numerically where the experimental values of the breakdown field are available. These have been measured, and the calculation yields the *oscillation amplitude limit* of Fig. 3.

[7] A. D. McDonald, and S. C. Brown, "High frequency gas discharge breakdown," *Phys. Rev.*, vol. 75, p. 411; February, 1949; vol. 76, p. 1634; December, 1949.

[8] E. W. B. Gill and R. H. Donaldson, "The sparking potential of air for high-frequency discharges," *Phil. Mag.*, vol. 12, p. 719; September, 1931.

Phenomena Outside Diffusion-Controlled Breakdown

Many experimenters have studied rf breakdown outside the limits set by the diffusion theory. The phenomena in these regions are complicated by secondary effects similar to that found in dc discharges. For example, when the oscillation amplitude limit is crossed, the work of Githens[9] and Thomson[10] gives the sudden increase in the breakdown voltage $E\Lambda$ shown in Fig. 3. The increase probably results from the increase in electron loss because of the amplitude of the oscillation forcing the electrons against the walls and hence out of the discharge. They found that this hump, shown in Fig. 3, flattened off, and later work by Gill and von Engel[11] showed that the breakdown field thereafter decreased. This decrease, being a function of electrode material, is due to a new source of electrons entering the discharge from secondary-electron production by the electron bombardment.

Some work has also been carried out measuring the breakdown at high frequencies below the mean free-path limit.[12] Here again the phenomena become complicated by the increased loss and the introduction of secondary effects, and the problem again approaches the difficulty of a dc discharge.

Effect of a Superimposed DC Field

The gas in a tube will break down when the losses of electrons to the walls of the tube are replaced by ionization in the body of the gas. When an ac field alone is applied, electrons are lost by diffusion. When a small dc sweeping field is applied, electrons are lost both by diffusion and mobility and the ac breakdown field will increase. The breakdown condition can be formulated mathematically by a consideration of these processes.[5]

Equation (8) described the particle current flowing through a unit area due to the phenomenon of diffusion. When the electron current is due not only to diffusion but also to the motion due to an electric field, one may write similar equations for the electron loss by adding a mobility motion term. Thus we can have:

$$\Gamma = -D\nabla n - \mu E_{dc} n \tag{26}$$

and

$$\nabla \cdot \Gamma = -D\nabla^2 n - \mu E_{dc}(\partial n/\partial z). \tag{27}$$

Equivalent to (10) we may write

$$\partial n/\partial t = D\nabla^2 n + \mu E_{dc}(\partial n/\partial z) + \nu_i n + S. \tag{28}$$

In a similar fashion to the solution obtained for the electron density in (13), (28) may be solved for the case of a cylinder of axial height L and axial coordinate z, radius R and radial co-ordinate r by the method of separation of variables to yield

$$n = (\text{constant}) J_0(2.4r/R)[\sin \pi z/L] e^{(-\mu E_{dc} z/2D)}. \tag{29}$$

In this expression the term in the zero-order Bessel function represents diffusion to the cylindrical walls of the tube; the sine function represents diffusion to the end walls; and the exponential represents the deformation of the sine caused by the sweeping of electrons by the dc field. This solution is subject to the condition $\nu_i/D = 1/\Lambda_{dc}^2$, where Λ_{dc} defines a modified diffusion length given by the relation

$$1/\Lambda_{dc}^2 = 1/\Lambda^2 + [E_{dc}/(2D/\mu)]^2. \tag{30}$$

For this case, the characteristic diffusion length is given by $1/\Lambda^2 = (\pi/L)^2 + (2.4/R)^2$, which is the diffusion length previously discussed for cylindrical tubes.

The only difference between the breakdown condition in the ac-dc case and the pure ac case is the substitution of a modified diffusion length Λ_{dc} for the characteristic diffusion length Λ. It will be noted that the modified diffusion length of a cavity is smaller than the characteristic diffusion length. A cavity whose electron losses are increased by a dc sweeping field is equivalent to a smaller cavity without a sweeping field.[5]

Superimposed Magnetic Field

The discharge breakdown at high frequencies in the presence of a constant magnetic field has been studied by a number of workers[13] in the diffusion-controlled region. Let us consider the motion of an electron between collisions under the influence of an electric field along the x axis, $E = E_0 e^{j\omega t}$, and a constant magnetic field B along the z axis. The equation of motion similar to (1) is then

$$m(d\vec{v}/dt) + e\vec{v} \times B = -eE_0 e^{j\omega T}. \tag{31}$$

The solution of this equation corresponds to the superposition of a circular helical motion and a plane elliptical motion. For the helical motion whose axis is along the magnetic field, the velocity oscillates at the cyclotron frequency $\omega_b = eB/m$ and the energy of this motion is constant. For the elliptical motion the velocity oscillates at the frequency of the applied field and the energy is determined by the magnitude and frequency of the applied field.

The mean energy gain between collisions of the electrons with the gas atoms can be obtained as before, con-

[9] S. Githens, "The influence of discharge chamber structure upon the initiating mechanism of the high frequency discharge," *Phys. Rev.*, vol. 57, 822; May, 1940.

[10] J. Thomson, "Sparking potentials at ultra-high frequencies," *Phil. Mag.*, vol. 23, p. 1; January, 1937.

[11] E. W. B. Gill and A. Von Engel, "Starting potentials of electrodeless discharges," *Proc. Roy. Soc.*, vol. 197A, p. 107; May, 1949.

[12] E. W. B. Gill and A. Von Engel, "Starting potentials of high-frequency gas discharges at low pressure," *Proc. Roy. Soc.*, vol. 192A, p. 446; February, 1948.

[13] J. S. Townsend and E. W. B. Gill, "Generalization of the theory of electrical discharges," *Phil. Mag.*, vol. 26, p. 290; August, 1938.

A. E. Brown, "The effect of a magnetic force on high frequency discharge in pure gases," *Phil. Mag.*, vol. 29, p. 302; March, 1940.

B. Lax, W. P. Allis, and S. C. Brown, "The effect of magnetic field on the breakdown of gases at microwave frequencies," *Jour. Applied Phys.*, vol. 21, p. 1297; December, 1950.

sidering the input power to an electron as $P=eEv$. By a suitable averaging of the velocity and averaging the energies over the collision times, the mean energy gain between collisions can be determined as

$$u=(eE_0^2/4m)\{1/[(\omega+\omega_b)^2+\nu_c^2]+1/[(\omega-\omega_b)^2+\nu_c^2]\}. \quad (32)$$

At low pressures where the collision frequency approaches zero, the energy approaches twice the energy of the elliptical motion of the electron. At higher pressures, such that there are many collisions per oscillation, the energy of the elliptic motion loses its meaning and the collision energy becomes $eE_0^2/2m\nu_c^2$. One can use (32) to define an effective field E_e which is the rms field at high pressure, and (32) may be written $u=eE_e^2/m\nu_c^2$. This concept is useful when the collision frequency ν_c is independent of velocity since this single function takes into account the effects of frequency and magnetic field on the energy. At low pressures the effective field has a maximum at resonance with the cyclotron frequency, as shown in Fig. 6.

The electrons produced by ionization have initially very little energy, but this increases in steps of u until the energy reaches the ionization energy u_i, disregarding excitation collisions. The number N of free times to

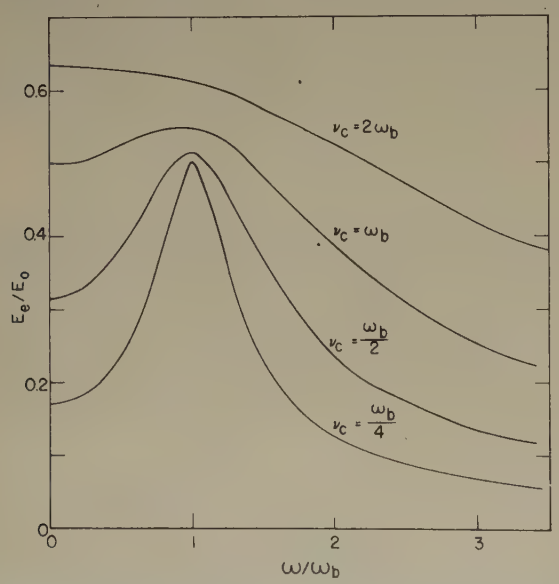

Fig. 6—The effective field as a function of the frequency showing the resonance in the presence of a magnetic field.

ionize is $N=u_i/u$ when ν_c is constant. The electrons thus double their number by ionization every N collisions; unless some equally effective process exists which removes electrons, their number will increase exponentially. Here we are considering electron diffusion to the walls of the discharge tube to be the balancing process. In the absence of the magnetic field, the random-walk theory[14] gives the mean square distance $\Lambda^2=Nl^2/3$ reached in N free paths of mean square length l^2, so that if the average electron reaches the wall in a distance Λ the diffusion process will just balance ionization. This is the condition for breakdown, and it may be written

$$u/u_i=l^2/3\Lambda^2=v^2/3\Lambda^2\nu_c^2. \quad (33)$$

If there is a magnetic field, u will be altered according to (32). At the same time the diffusion theory must be altered to take into account the curved paths between collisions. This may be done by appropriately decreasing the mean free path or increasing the diffusion length. We shall adopt the latter and denote the new length by Λ_e, where

$$\Lambda_e^2=[(\omega_b^2+\nu_c^2)/\nu_c^2]\Lambda^2. \quad (34)$$

The effect of a magnetic field is to make the dimensions of the tube at right angles to the field appear larger to an electron.

When the mean free path is much smaller than Λ_e, the intercollision energy gain u is correspondingly smaller than the ionization potential. From (33) we see that breakdown should occur at the same effective field if the ratio of the mean free path to the effective diffusion length is the same. That is, the effective field for breakdown is a function of $p\Lambda_e$ only. Combining (32) and (33) we obtain

$$E_e^2=2uu_i/3\Lambda_e^2. \quad (35)$$

We saw in (34) that the effect of a magnetic field is to make the dimensions of the tube at right angles to the field appear larger to an electron. Equation (35) shows that this should reduce the effective field for breakdown in the same proportion.

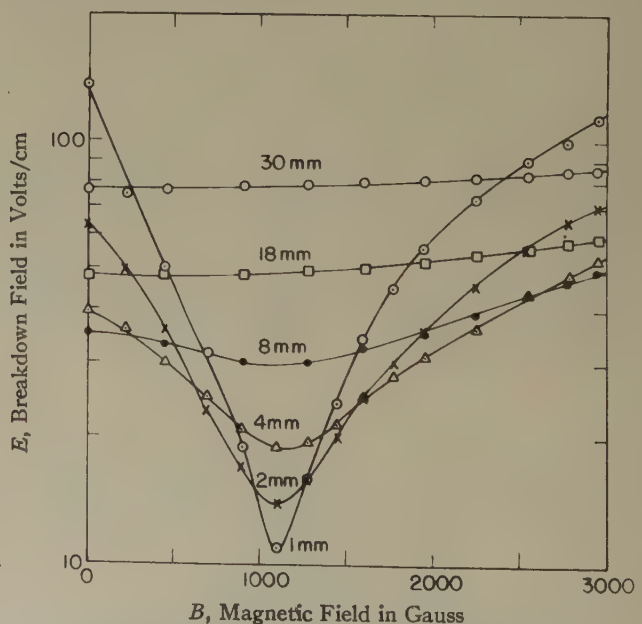

Fig. 7—Breakdown of helium in transverse electric and magnetic fields.

Experimental data for breakdown in Heg, which again agree with our simplifying assumptions of constant ν_c and no loss of energy to excitation, are shown in Fig. 7. The result of plotting the effective field in place of the actual field would be to remove the resonance effect of the magnetic field.

[14] E. H. Kennard, "Kinetic Theory of Gases," McGraw-Hill Book Co., Inc., New York, N. Y., p. 271; 1938.

We have just been discussing the case in which the electric field and the magnetic field have been mutually perpendicular. If the two fields are oriented in the same direction, the effect is one of changing the diffusion only. Experimental breakdown curves in Heg gas for this case are shown in Fig. 8.

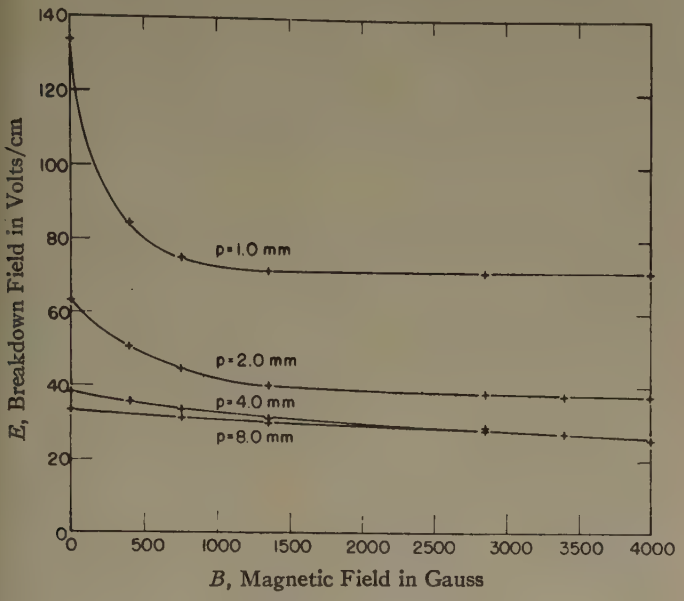

Fig. 8—Breakdown of helium in parallel electric and magnetic fields in a cylindrical cavity.

Conclusion

In summary it can be said that high-frequency gas-discharge breakdown is much simpler than dc-discharge breakdown because of the absence of necessary secondary effects. In all physical cases so far studied, the governing loss mechanism has been diffusion of electrons to the boundaries of the tubes. Although detailed calculations of the diffusion processes lead to considerable mathematical complexity, simplified theories based on the behavior of the average electron are quite adequate for many cases. Superposition of dc and magnetic fields on the hf field affect the breakdown in general as they modify the diffusion loss of the electrons.

Limits can be set on the application of the diffusion process; when breakdown is studied outside these limits, the discharge becomes complicated by the same secondary phenomena as are present in a dc discharge, even if the electric field oscillates at a radio frequency.

Simulation—Its Place in System Design*

HARRY H. GOODE†

This paper is published with the approval of the IRE Professional Group on Radio Telemetry and Remote Control, and has been secured through the co-operation of that Group.—*The Editor.*

Summary—**The place of simulation in system design is developed in relation to all other steps in the design process. From this, the relation of simulation to both the analytical attack, on the one hand, and to a final operational system, on the other, is developed. This leads naturally to the program to be followed in a simulation setup. In this discussion the pitfalls to be avoided are emphasized. Then simulation of a human link in a system is discussed. Finally, a critique of simulation is given with relation to cost, time, difficulty of execution, treatment of nonlinearities, and noisy inputs.**

Introduction

WITH THE ADVENT of the large, fast computer many extreme statements were made, pro and con, about the use of simulation in system design. Yet, like any other tool, simulation is what its user makes it. It can be a powerful aid to the skillful worker.

It is the purpose of this paper to describe this tool, expound and exemplify its use, and give it its proper place in design procedure. To avoid spending time disagreeing as to the nature of simulation, let us adopt a viewpoint to serve for this discussion alone. Simulation, we will agree, is a tool for the study of a system by the cut-and-try examination of its mathematical representation by means of a large analog or digital computer. The mathematical representation is assumed to be made up of separate expressions, each concerned with a system component. This definition will be too broad for some, too narrow for others. However, it will serve to delimit the present discussion.

Recently, in the course of the work of a Research and Development Board panel concerned with simulation, a program for system design was stated which, with some modification, will serve as an outline for this discussion. This modified program consists of

1. Description of system inputs
2. First-order design
3. Component analysis
4. Experiment for required parameters
5. System analysis
6. System simulation
7. Modification toward an optimum system by repeating steps (2) through (6).

This ordering of the design steps gives a proper perspective to the position of simulation in the scheme of design.

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These steps require explanation. The statement of system inputs is, of course, worth a greater expenditure of time than most give to it. Too frequently the system finally designed operates best for inputs which may never occur in practice. The expected ranges of input variables, the frequency spectra, and the multiplicity of inputs should be explicitly stated. If chance disturbances of the inputs are expected, an attempt should be made to determine the power spectrum and amplitude of the noise.

Passing now to the creation of a first-order design, this step displays the essential difference between the experienced designer and the novice. The former, for a stated set of inputs, can usually choose a reasonably adequate-looking block diagram of a system which will meet these inputs. The ability to do this is the intangible, "know-how." At Michigan we have found it desirable to stop at the first-order design and attempt a description of the proposed system operation based on a quick look at the first-order design. This may lead to obvious modifications since the system may be unable to carry out steps which seemed obvious at first.

At this point component analysis begins in earnest. The tools for such an investigation are mainly analytical. The questions to be answered are mainly subsystem questions. What input may be expected at Component X, and what will its resultant output be? If it is linear, what is its transfer funcion? If it is not linear, suppose it is linearized and describe its performance. Are tests available on this type of component; if so, how did it perform?

In the course of component analysis, experimental values will frequently be lacking. An extensive experimental program may be needed to obtain the values required to describe component performance.

While small-scale simulations may be useful at any time, advocates of the use of system simulation have often urged its use at many of the points along the route just followed. However, in the author's opinion one is not yet ready to pay the price of a system simulation. A system analysis using linear analytic methods will profitably eliminate obviously bad system setups and indicate regions in which further investigation is desirable. The analyst, if he arrives at an expression for the system at all, will be able to investigate complicated parameter regions and may even be able to approximate an optimum set of parameters. But with all this done, the system must be tried, and no complicated system can, with economical reason, be built, tried, and discarded. This latter technique, by the way, is too often used even today. Here is where simulation pays its way; its cost will be discussed later.

In the course of the above steps, the system was, of necessity, represented mathematically. Using the definition of simulation given above (i.e., that it is a tool for the cut-and-try examination of such a system's mathematical representation) the system can be set up and its performance observed. Simulation makes this possible at a reasonable cost.

Assuming the simulation completed, it is possible to designate the places at which the system fails, or performs badly. The designer may then return to the first-order design and make the necessary modifications in preparation for repeating his design steps. Of course, in practice the time order of these design steps is not as clear-cut as we have made it here. It is indeed a mythical engineering staff that has the leisure to proceed in such an orderly fashion.

It is desirable to discuss in more detail the relationship of simulation to its two chief competitors in the system-design process. On the one hand, simulation must be compared with the methods of analysis (i.e., mathematical analysis); on the other hand, it must be viewed as a substitute for designing a system by the cut-and-try or build-and-discard method.

As pointed out above, analysis is powerful and decisive in an environment which allows acceptable linearization. In some relatively simple cases it may even deal with noisy system inputs. But with growing complications in the form of nonlinearities, and even discontinuities, with a long path through many boxes for noisy inputs and with human beings in the system, the analyst must surrender. Because it deals with nonlinearities, probability, and human beings in a somewhat more realistic fashion, simulation must supersede analysis in an environment containing such elements.

At the other extreme, the construction of an operational system allows test under conditions as they actually are simply because it is the system. However, for even moderately complicated systems the cost of construction is prohibitive of trial. Moreover, the time consumed in producing the system limits the number of trials. And finally, the control of observations when the system is built is difficult.

It should be noted that with increasing complication simulation as a substitute for the two extreme attacks stands out more and more prominently as the preferred method. Analysis must be relegated to a preliminary role and operational construction to the final product since the reasons above increase in importance with complication.

When the decision to use simulation has been made, it is necessary to know something about available automatic computing machines. When this paper was planned, it was intended that a short summary of available machines would be given. However, much more on the subject may be gained from the April, 1950 issue of the PROCEEDINGS OF THE I.R.E., where a bibliography on computing machines appears.[1]

We go on, therefore, to examine in detail the execution of a program of simulation. It follows from the previous steps of system design that a detailed mathematical statement of the system has evolved. The simulation program will entail the following steps, each of which will be discussed further:

1. Choice of computer
2. Programming
3. Choice of cases to be treated

4. Coding (or circuit mapping)
5. Machine setup and debugging
6. Running
7. Data reduction
8. Analysis of results
9. Reporting.

I. Choice of Computer

In choosing a machine it will be necessary to consider the type of problem to be solved. The first choice is between analog and digital computers. Those problems which are essentially the solution of a large set of differential equations fall to the lot of the analog machine. Thus, mechanical systems, aircraft-systems designs, and energy-supply systems are all naturally suited to the analog machine. On the other hand, problems which require many discrete steps and logical choices fall into the digital computation category. Telephone systems, some systems planned for warfare, and traffic systems are digital problem types.

Suppose the machine chosen is of the analog type. The next problem will be the capacity required, a question answered directly from an examination of the mathematical statement of the system with regard to the number of operations, such as integrations, additions, etc., required in the problem. The capacities of various machines, of course, differ with regard to the type of mathematical operations which they can perform.

Having determined the capacity of the machine necessary, a joint consideration of accuracy and speed of response will be necessary. If the accuracy requirements are high, it will be necessary to pay in time of a run in order to stay within the speed of response of the machine chosen. If, on the other hand, accuracy requirements are not great, the speed of response will not be a factor and one may run as fast as the machine allows. In case the first situation holds, in which accuracy requirements are high, it may be necessary to rule out using machines with slow response because of the time which has been added to a run. It will be seen later that the number of runs will be chosen on a quite different basis. If this number is large, some interplay between these factors and the number of runs will be necessary in deciding upon a machine.

If the problem is one for the digital computer, it will be necessary to consider the problem from the point of view of initial data versus computation. If the problem is one in which a small amount of data is fed to the machine and a large amount of computation is necessary, the output being relatively small, any of the machines designed for scientific application are satisfactory. However, if the problem requires a large amount of data to be put in, a small number of computations to be performed, and a large amount of information to be put out, some of the business machines will be more to the point. Finally, a type of problem which has been developing in our work requires that a large amount of data be stored, a large amount of computation be performed, and a large amount of information be put out. The machine suited to this type does not exist at present, but it will probably be available within the next year.

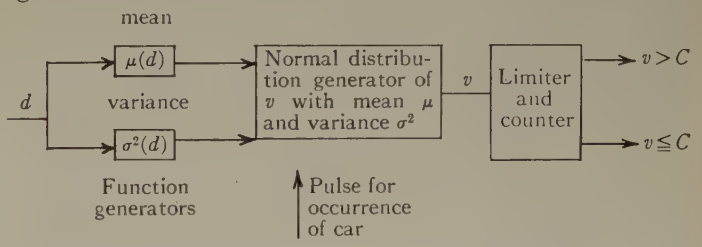
Having decided on the machine to be used from the standpoint of capacity, it will be necessary to consider accuracy requirements and speed of response, as for the analog machine. However, for the digital machine, this consideration falls most naturally under "Programming."

II. Programming

After the mathematical statement of the problem has been made in great detail, it may be found necessary to resort to simplifications. It is difficult to say without discussing a particular problem what these simplifications may consist of. They crop up in various contexts. Perhaps in later papers some account will be given of these simplifying methods. One broad principle in connection with those problems containing probability considerations is the following:

Where a set of boxes, to which the input is a given probability distribution, can be represented as an operator in the mathematical sense so as to provide the distribution of the output, the entire set may be substituted by directly generating, equipment-wise, the probability of the output.

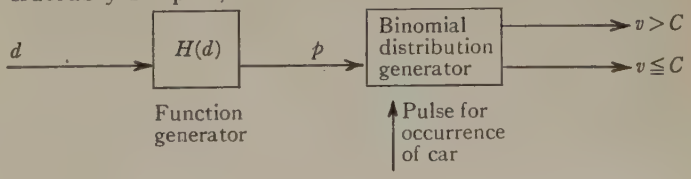
Suppose, for example, a traffic problem is being studied in which the occurrence of motorists' speed (v) is normally distributed with a mean and variance dependent upon the distance from a traffic intersection. Suppose further that the problem requires that each motorist traveling above a speed C will be stopped. Equipment-wise, this element of the problem may be generated thus:



However, a simple analysis show that $v \leqq C$ will occur with probability

$$p = \int_{-\infty}^{C} N(\sigma, \mu)dv = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{(C-\mu)/\sigma} e^{-y^2/2}dy = f(\mu, \sigma) = H(d)$$

so that we may substitute this diagram, which is considerably simpler,



When the mathematical setup has been simplified as much as possible, it will be necessary to consider various computational methods. In the analog computer this is generally a straightforward affair with components corresponding to mathematical operations. In the digital computer there will, in general, be alternatives for a

[1] "Radio progress during 1949," Proc. I.R.E., p. 373; April, 1950.

particular computational method. Thus, for an integration one may resort to an extremely short interval and use a simple tangent approximation of a function to obtain required accuracy. On the other hand, more sophisticated methods entailing high-degree polynomials and iteration may be used, resulting in a larger interval being permissible but requiring a larger number of computation steps within the interval. It is something of a problem to balance interval size and sophisticated methods against one another so that an approximation to the minimum number of computations for a given accuracy may be obtained.

Finally, with regard to programming, it is to be noted that the detailed consideration of the computational methods to be employed will suggest to the designer questions about his original design and sometimes make it possible for him to better his original system merely from a consideration of these methods. This will occur most frequently when the system itself contains many computational processes. The attempt to simplify the simulation computation will result in a simplification of the actual system computation.

III. Choice of Cases

The next steps in the execution of the program are the choice of the cases to be run, measures of effectiveness to be used, methods of reduction of data, and the determination of the total number of runs to be made. In choosing the cases to be run, nothing will substitute for experience in doing a problem. However, some general notes are as follows:

The designer should permit great flexibility in changing these runs when, in the course of examining the outputs, necessary changes become evident. There is some tendency to set up a program of runs and drive it to the bitter end in spite of the fact that the designer knows, early in the game, that he will have to change the direction of his investigation.

Again, before running on a full program it is desirable to sample a few points. This may result in a complete shift of the emphasis, which was chosen on an *a priori* basis as the result of analysis. In choosing values in a given variable range it is desirable to have at least three values. These, as nearly as possible, should be located at the minimum and maximum reasonable values and at a guessed optimum. From these values, one obtains some knowledge of the curvature of the function being used as a measure of effectiveness.

The smaller the number of design variables permitted the easier will be the execution of the program. Where possible, consideration of some design variables should be eliminated on the basis of the preliminary analysis. Otherwise the number of runs required becomes excessive, even for today's fast machines.

With regard to measures of effectiveness, it is desirable to use as few as possible for the evaluation of the results. To a large extent, the choice of these measures is inherent in the physical problem. However, cases have occurred where redundant measures of effectiveness have been used. It is worth the time necessary to eliminate such redundancies since they serve only to confuse the designer when he evaluates his results. It is desirable that measures of effectiveness be dimensionless. The purpose of this is to enable the designer to extrapolate from the results of cases run to those cases which have not been run, but whose parameters in dimensionless form are the same as those already run. Where possible, the quantity used should have a readily apparent meaning.

It will pay the designer to know what his final answers will look like. The effort expended toward this end will minimize the number of unnecessary steps taken in the course of simulation. Moreover, knowing the required answer leads immediately to a choice of the variables to be recorded, which in any machine of modest size is by no means a trivial problem. Recording facilities will, in general, be found to be limited, and a well-considered choice of variables will be profitable. At this point, it is well to consider also the possibility of cutting down human computation by making the outputs of the machine as nearly like the final form as possible. This will not always be permissible because of the amount of equipment used up in relatively unnecessary computations; however, where such equipment is available, much will be gained by putting out final results directly from the machine.

The number of runs to be made at a parameter space point in a system subject to chance occurrence is a difficult question to answer without some experience with the problem at hand. The designer usually has no time for a detailed statistical analysis by which the significance of the values he is obtaining may be determined. Such a statistical analysis is frequently a larger problem than the system analysis. However, there are some compensating factors. It is found that in the ordinary run of problems convergence toward a stable value for the measure of effectiveness is fairly rapid. In our experience about 70 runs at a point determine the required function at that point within adequately close limits. If there are no probability considerations in the problem, only one correct run will, of course, be necessary at any point.

IV. Coding (or Circuit Mapping)

The definition of "circuit mapping," as used here, applies to an analog machine, and is that step in the computational procedure concerned with the choice of the particular circuit to be followed through the machine. There is a choice of using highly trained or technical personnel to execute this step, with a resultant saving in equipment for performing a particular operation, or of using personnel without such technical qualifications and thereby absorbing equipment at a much higher rate. The designer will have to make this choice on the basis of the personnel and facilities available to him.

A careful look at the circuit map will prevent hasty conclusions concerning what the machine is actually

computing. A detailed examination of the circuits being used may prevent many hours of search and wonder. A technique which has been found useful in our work has been the maintenance of a one-to-one relationship between the boxes in the actual system and the diagram of the computational components used in the machine. This has two useful results: It enables the trouble sites to be located more easily and it allows the designer to visualize, with greater ease, what is happening in the simulator.

The corresponding operation to circuit mapping for the analog machine is coding for the digital machine. Here too, time spent in checking and rechecking the coding will pay off in less time consumed for false runs.

With regard to probability operations in the digital machine, a number of techniques have been evolved for the generation of random numbers. There is a much better control of the distribution generated in a digital machine than on the analog machines where one is at the mercy of physical processes for generating such distributions.

V. Setting up the Machine

Where possible, a removable plug board, such as that which the Reeves people have recently added to the REAC, should be employed on an analog machine. This arrangement is desirable from the point of view of an organization concerned with several problems. It makes possible having two or more problems set up on the machine. Time may then be shared among the problems. It is then possible for engineers on one problem to examine results while another problem is being run.

The choice of display from the machine is of some importance. We have found it useful to make this display as graphic as possible in terms of the geometry of the real system.

VI. Running the Problem

Notes about running the problem are as follows:

When possible, data reduction should be carried on as the machine completes each run; the results may then be monitored for any required re-orientation of the program. The design engineer can frequently spot an obvious difficulty or need for change, thus reducing the number of runs and, therefore, time and cost expended.

The time per run may sometimes be cut by running the problem on a fast time scale. In case such a procedure is adopted, it is necessary to consider carefully the operations involved so as to be certain that the actual system conditions are not being violated.

It will be necessary to have some kind of check to determine if the machine is turning out correct results. In cases where probability is not a consideration, hand-computed solutions for relatively simple conditions will furnish a clue to whether the machine is operating properly. Where probability enters into the system, it will be necessary to check the problem with a "no noise" condition and to accept the results of probability runs as correct when those with no noise have turned out correctly. For this purpose, the outputs of the original probability distribution generators should be recorded and frequently tested.

VII. Data Reduction

As pointed out above, it is desirable to know what the final answers will look like before the runs begin. It is even more desirable to choose the methods of data reduction in advance. These methods may run all the way from a simple tabulation of the result turned out by the machine to a complicated graphical and analytical method of obtaining the measure of effectiveness.

In large organizations, it is administratively desirable to clarify the responsibility involved in following the simulation through the steps outlined above.

For completeness, the steps of analysis and reporting have been added to the outline given above. These two steps will require the direct attention of the system designer since they lead directly to the future course of action in the system design.

A subject deserving special discussion in connection with simulation is the human being treated as a simulated member. Several levels of realism required may be distinguished. For those systems in which decision making is his function, it is frequently satisfactory to represent the human being's response by a time delay. In air traffic control, for example, the response of a pilot to a voiced command will be delayed. A normal distribution of delay times about a measured average may be adequate.

If his response is functional, the problem becomes difficult and attempts to represent his presence have been weak. The reasons for this are threefold: The human being is a nonlinear device whose functional response is difficult to obtain; his functional response is dependent upon his recent past history; even where response is a reasonably well-known functional form, numerical values are difficult to obtain.

This state of affairs usually leads to an attempt at simulating the system and putting a real human being into it—offering him the proper operational stimuli and furnishing him with operational controls for response. It is frequently not realized, after all this trouble is taken, that one or two human beings do not adequately represent the population from which the ultimate system operators will be drawn. It is desirable in those cases in which the human being is a factor to consult with both the psychologist and the statistician.

Finally, it is desirable to mention some of the frequently quoted remarks about simulation and discuss their implications:

1. "Simulation is costly": Simulation costs have been estimated at a fraction of a cent per run, and an actual cost of $15,000 a run has occurred in a recent government-sponsored experiment. But the correct answer on cost is a complicated one. It depends on the problem, on the extent of realism required, on the familiarity with the system, on the reliability of the equipment used, etc.

However, no one now doing simulation would suggest an order of magnitude under dollars per run, and probably no one would accept as necessary over $100 per run. The way to measure cost is not in absolute number of dollars but in the cost of doing without. At its worst, this may mean the building of a useless system.

Trajectory calculation is a fair measure of run cost on some typically complicated current systems. Rough estimates of these costs for a few machines are: differential analyzer at M.I.T.—$30, Cyclone at Reeves Instrument Corporation—$15, Meteor at M.I.T.—$25, and Mk I at Harvard—$30.

2. "Simulation is easy": Simulation is not easy; it requires deep understanding of the problems being solved, the booster of simulation notwithstanding. Just as the physicist must decide what factors are *a priori*, irrelevant to his experiment, so must the system designer be able to point out simplifications which will lessen the detail in setting up the system, but will not vitiate the results.

In this connection, it has been found desirable in our work to state explicitly the ways in which the simulation we undertake differs from the real system. This has two useful purposes: a. The limitations of the results are expressly stated and conclusions are, therefore, warily drawn. b. When these limitations are too great, a solution to the obvious problem of the need for increased scope, complexity, and realism of the simulation is sought.

3. "Simulation complexity vitiates results": This can certainly be true if care is not exercised. However, two notes are of importance here: First, the complicated group of components may frequently be substituted by the result of a previous analysis and simulation of the group of components. The greatest exercise of both care and ingenuity are necessary in this regard. Secondly, the performance of analog gear in this respect has amazed those using it for large and complicated systems. It is true that an inherent accuracy of 0.1 per cent of full-scale reading for any one component is all that the average user can afford. It is also true that errors in such components, if used in an open-ended chain, will pile up according to known laws. However, in most systems of complexity many closed loops occur, and the system itself is usually a large closed loop. This results in our experience showing an error of less than 0.5 per cent of full scale maximum allowable answers due to computation for problems involving as many as 90 operational amplifiers (or, put another way, in computations with upwards of 100 fundamental mathematical operations).

4. "Simulation is fast": To the engineer waiting for results on a system simulation, it is certainly not fast. Yet the true measure of speed lies in what comparable operational tests of equipment, if available, would require in time. Then, no matter how slow the computer, no matter how many bugs occur in the setting up, and no matter how many human computers make errors in reducing data, simulation is fast—at least tenfold over operational attempts.

Of course, accuracy may be paid for with time, as usual. In the analog setup, if the system input contains high frequencies, a slow time scale is necessary to allow computational components time to respond. With the digital computer, the payment is again in time, with the necessary iterations for integration accuracy, or the choice of a small-time increment for high-frequency response. But over-all simulation is fast.

It should now be clear that, without minimizing its difficulties, simulation is a powerful tool.

The Civil Aeronautics Administration VHF Omnirange*

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Summary—**This report describes the development of a vhf-omnirange system, operating in the frequency band of 112 and 118 mc. The range furnishes magnetic-bearing information with respect to the range station, and provides definite track guidance between the station and any point within its service area.**

The omnirange produces two 30-cps signals: one is constant in phase and independent of the aircraft's position, and the other varies in relative phase directly in accordance with the magnetic bearing of the aircraft from the station. A phase-measuring device in the receiver enables the pilot to determine his magnetic bearing with respect to the station, and to select and fly a range course on any desired magnetic bearing.

The accuracy of the system, including the receiver plus ground equipment, in operation at the Civil Aeronautics Administration Experimental Station, Indianapolis, Indiana, is approximately 1.5 degrees. The ground equipment has been in continuous operation for more than 3 years.

The vhf omnirange has been selected as part of the common Civil-Military System, Transition Program, as recommended by the Radio Technical Commission for Aeronautics.[1]

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[1] Report on Air Traffic control, prepared by Special Committee 31.

INTRODUCTION

IN PLANNING a system of airways as a means of navigation for all aircraft and facilities for the separation and maintenance of a continuous flow of a large volume of traffic, it becomes apparent that

radio ranges defining courses or tracks in only a few directions are inadequate.

The CAA has carried out the development of two-course visual, two-course aural vhf ranges in accordance with recommendations made by the Radio Technical Commission for Aeronautics in the summer of 1939. Development was completed early in 1942, but the conversion of the airways to vhf-range operation was interrupted by World War II. Just prior to 1945, however, the conversion program was resumed on a limited scale with the establishment of the Chicago-New York vhf airway. Simultaneously, the CAA had been working on the development of a vhf omnidirectional radio range, along the principles proposed by D. G. C. Luck of RCA, at the Kansas City meeting of the RTCA in the summer of 1939. Progress on this development has taken such a promising turn that two-course vhf ranges were rapidly superseded by omnidirectional vhf ranges, more commonly referred to as "omniranges."

The general principle of the omnirange dates back to Lee de Forest, who proposed rotating a radio beam keyed to identify the sectors forming the 360-degree sweep of the beam.[2] Another omnirange was developed, using a rotating beam; however, an omni-identification signal was transmitted each time the beam passed through north.[3] The beam rotated clockwise so that the time interval between the omnisignal and the beam alignment with the observer, measured by means of a stop watch, would be a measure of the observer's azimuth. A practical form of this type of range was developed in England by rotating a loop antenna.[4] Later this rotation was accomplished electrically.[5] A purely electrical means of rotating a field pattern for use in an omnirange has been proposed.[6,7,8] The omnirange developed by RCA was described in a paper by Luck.[9] In a paper[10] presented before the RTCA annual meeting in January, 1945, Stuart, Director of the Office of Technical Development, described an early model of the CAA omnirange.

The present omnirange has elements in common with other types of radio ranges and direction-finding systems, and represents a refinement in practice rather than a fundamental departure in principle. It may be likened to the standard four-course aural radio range, with a means provided for precisely determining the ratio of the two signals at any point and thereby the azimuth from the station at any point, rather than at points lying only on certain specific courses where the signal ratio is unity.

The antenna system, which is so widely employed in direction-finding and radio-range systems, is the familiar arrangement of five radiating elements located at the corners and the center of a square. Opposite pairs of antennas are operated 180 degrees out of phase, and the electrical spacing between the elements is small compared to the wavelength, resulting in a figure-of-eight field pattern. This field pattern is rotated, so to speak, by means of a capacity goniometer, which is driven by a synchronous, 1,800-rpm motor. The rotating goniometer acts as a balanced modulator, eliminating the carrier frequency and supplying sideband energy at a carrier frequency ± 30 cps to the two antenna pairs. Since the entire field is, in effect, rotated once for each rotation of the goniometer, it is obvious that each direction in space will have a certain phase of the rotational frequency associated with it, and that this phase will change degree for degree with a change in azimuth relative to the station. If we have a signal supplying a 30-cps voltage of reference phase which is independent of the azimuth, we can determine the azimuth from the station by comparing the phase of the two 30-cps signals.

The purpose of this report is to present a description of the latest CAA omnirange system and to indicate what improvements have been made over the earlier model.

Ground-Station Equipment

General

A block diagram of the essential components of the ground-station transmitting equipment is shown in Fig. 1. A conventional vhf transmitter has its final stage

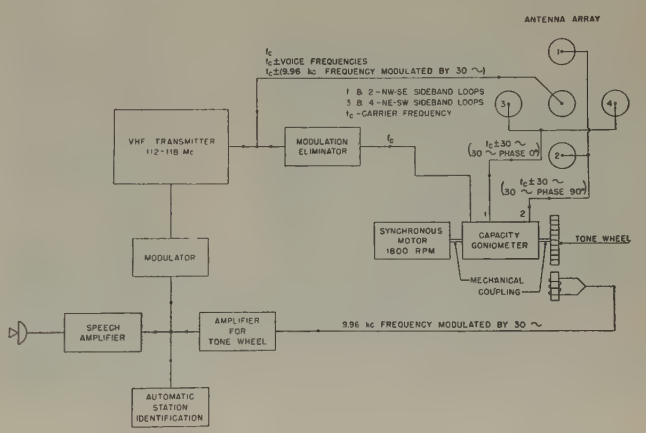
ANTENNA ARRAY
f_c
$f_c \pm$ VOICE FREQUENCIES
$f_c \pm 9.96$ kc FREQUENCY MODULATED BY 30 ~
1 & 2 - NW-SE SIDEBAND LOOPS
3 & 4 - NE-SW SIDEBAND LOOPS
f_c - CARRIER FREQUENCY
VHF TRANSMITTER 112-118 Mc
MODULATION ELIMINATOR
$f_c \pm 30$ ~ (30 ~ PHASE 0°)
$f_c \pm 30$ ~ (30 ~ PHASE 90°)
SYNCHRONOUS MOTOR 1800 RPM
CAPACITY GONIOMETER
TONE WHEEL
MODULATOR
MECHANICAL COUPLING
SPEECH AMPLIFIER
AMPLIFIER FOR TONE WHEEL
9.96 kc FREQUENCY MODULATED BY 30 ~
AUTOMATIC STATION IDENTIFICATION

Fig. 1—Block diagram of vhf omnirange transmitting equipment.

amplitude modulated by a subcarrier and simultaneous voice. The subcarrier itself is frequency modulated at 30 cps. The output from the final stage is fed to the center antenna of the five-loop array and also to the input of the modulation eliminator. A goniometer functions as a mechanical sideband generator and delivers 30-cps sideband energy to its output circuits. Output

[2] United States Patent No. 833,034; 1906.

[3] J. Zenneck (Trans. Seelig), "Wireless Telegraphy," McGraw-Hill Book Co., New York, N. Y., p. 368; 1915.

[4] T. H. Gill and N. F. S. Hecht, "Rotating loop radio transmitters and their applications to direction-finding and navigation," *Jour. Inst. Elec. Engrs.*, vol. 66, p. 256; 1928.

[5] H. A. Thomas, "A method of exciting the aerial system of a rotating radio beacon," *Jour. Inst. Elec. Engrs.*, vol. 77, p. 285; 1935.

[6] P. H. Evans and J. W. Grieg, United States Patent No. 1,933,248; 1933.

[7] J. W. Grieg, United States Patent No. 1,988,006; 1935.

[8] G. H. Brown and D. G. C. Luck, United States Patent No. 2,112,824; 1938.

[9] D. G. C. Luck, "An omnidirectional radio-range system," *RCA Rev.*, pt. I, vol. VI, no. 1; July, 1941; *RCA Rev.*, pt. II, vol. VI, no. 3; January, 1942; *RCA Rev.*, pt. III, vol. VII, no. 1; March, 1946.

[10] D. M. Stuart, "The omnidirectional range," Presented before the RTCA Annual Meeting; January, 1945; later published in *Aero Digest*; June 15, 1945.

Number 1 of the goniometer delivers 30-cps sideband energy of zero-degree audio phase to one pair of diagonally opposite loop antennas. Output Number 2 of the goniometer feeds 30-cps sideband energy of 90-degrees audio phase to a second pair of diagonally opposite loops. The four antennas are arranged in the form of a square around the center loop antenna and are fed in such a manner as to produce two figure-of-eight field patterns. The two figure-of-eight patterns are in phase quadrature in both space and time, and can be visualized as a single figure-of-eight pattern with a positive lobe and negative lobe rotating at an audio rate of 30 cps, which produces amplitude modulation (in space) of the main rf carrier transmitted from the center antenna. This energy, when detected in a suitably designed receiver, is known as the "variable-phase" signal. The 30-cps signal produced in the receiver from the frequency-modulated subcarrier is termed the "reference-phase" signal. The purpose of the subcarrier modulation is to provide a means of discriminating between the two 30-cps voltages in the receiver.

Fig. 2—Omnirange ground facility.

Fig. 3—Omnirange transmitting equipment.

Fig. 2 is a view of a CAA omnirange ground facility using a 30-foot tower. The antenna array is situated inside the cylindrical housing on the tower. The transmitters and associated equipment located in the building on the ground are shown in Fig. 3. Approximately half the equipment is "standby" to permit maintenance while providing continuous service.

Antenna Array

The polarization most desirable for an omnirange operating in the 100-mc region of the radio spectrum was determined by experiment. The maximum amount of scalloping[11] was ± 3 degrees for the vertically polarized arrays and ± 0.7 degree for the horizontally polarized array. The site used for these tests was considered to be about average. Trees probably caused the scalloping which was observed.

The polarization used in the present omnirange system is horizontal, as a result of conclusions drawn from the early comparison tests. Fig. 4 shows the arrangement of the loop radiators and the approximate shape of the horizontal-plane field patterns. The pair of antennas with currents I_1 produces the figure-of-eight pattern E_{SB1}. Similarly, the pair of antennas with currents I_2 produces the pattern E_{SB2}. The center antenna with current I_A radiates the E_c pattern. The three patterns combine in space to produce an amplitude-modulated wave whose modulation frequency is $\rho/2\pi$. The most significant characteristic about this amplitude-modulated wave is the phase angle of the modulating frequency, which varies as the azimuth angle, ϕ, for small values of spacing, S.[12]

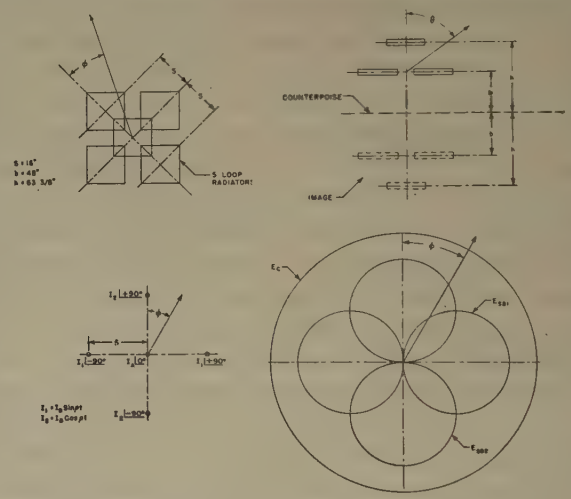

Fig. 4—Mechanical layout, currents of radiators, and theoretical horizontal-plane field patterns.

The diagonal spacing between each pair of sideband antennas is 112 degrees at midband, 115 mc. Each sideband antenna is mounted on top of a pedestal 168 degrees above the counterpoise. The carrier antenna also is supported by a pedestal 222 degrees above the counterpoise. The spacing between adjacent sideband an-

[11] Scalloping is defined as the amplitude of the course-deviation indicator's fluctuations due to the effect of reflections from trees, buildings, wires, the earth's surface, and the like.

[12] H. C. Hurley, S. R. Anderson, and H. F. Keary, "The CAA vhf omnirange," CAA Technical Development Report No. 113.

tenna sides is 10.5 degrees, and the sideband antennas are symmetrically disposed around the carrier antenna. Three rf receptacles are mounted directly under each loop transposition. Two of the receptacles are connected directly to the transposition. RF power is fed to the loop antennas through Type RG 8/U, solid, dielectric coaxial cable. Since the loop antenna is a balanced circuit, it is necessary to convert from unbalanced to balanced line in order to feed the loop in the proper manner. The conversion is accomplished by the use of an 180-degree section of unbalanced line.

Diagonally opposite pairs of sideband antennas are connected through 350-degree lengths of cable and are excited 180 degrees out of phase. This line length was found to be optimum at 115 mc for minimum parasitic currents in the sideband antennas, induced therein by the center antenna. The 180-degree phase relation is obtained by reversing the connections at the transposition in one loop antenna of each diagonal pair. One pair of sideband loops is fed from the goniometer output Number 1 and the second pair of sideband antennas from output Number 2. The center carrier antenna is fed directly from the transmitter output stage by coaxial cable.

Tests conducted to determine the operating characteristics of the vhf loop antennas included field measurements to obtain the horizontal-plane patterns, impedance measurements to ascertain impedance matching requirements, rf-current measurements to determine current distribution and balance around the periphery of the loop, and measurements of parasitic currents due to interaction between loops grouped together under normal operating conditions.

During the development of the omnirange it was found that the antenna shelter will produce errors if it is not cylindrical in shape (see Fig. 5). A square house was found to produce an octantal error curve of ± 1.5 degrees.

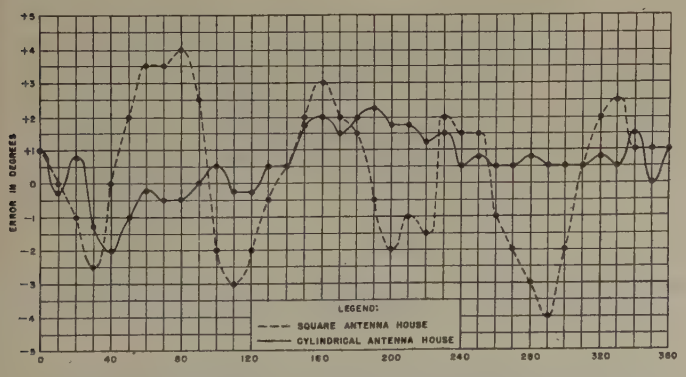

Fig. 5—Flight-calibration error with cylindrical and square antenna houses. Bearing selector in degrees.

Fig. 6 shows the vertical-plane field-strength pattern of the present omnirange antenna array mounted on 15- and 30-foot high counterpoises. The measurements were made from an airplane as it flew away from the station, and include the pattern of a horizontal-V receiving antenna located on top of the vertical stabilizer of a DC-3 airplane. It will be seen that the lobes, at small values of θ, are essentially independent of counterpoise height because the energy is reflected from the counterpoise instead of the ground. On the other hand, the lobes at large values of θ are dependent upon counterpoise height since little energy is reflected from the counterpoise at these angles and the earth reflects a considerable signal.

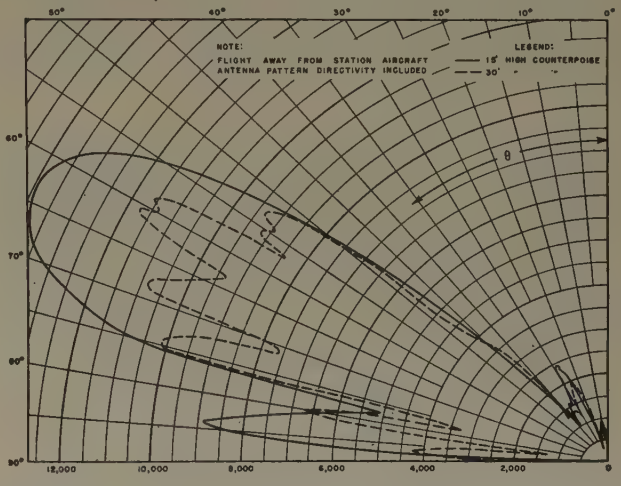

Fig. 6—Measured vertical-plane field patterns of antenna array mounted on 15- and 30-foot high counterpoise. Relative field strength.

Goniometer and Subcarrier Generator

The goniometer consists of two mechanical sideband generators on a common drive shaft, rotating at 1,800 rpm. One sideband generator is oriented 90 degrees with respect to the other so that the electrical outputs of the two generators are in phase quadrature at the modulation frequency, as shown in Fig. 7(a). The important

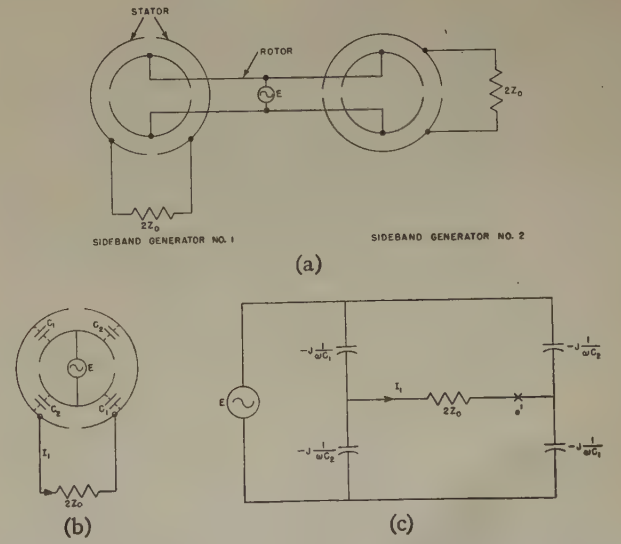

Fig. 7—(a) Arrangement of stator and rotor plates of goniometer. (b) A view of one-sideband generator of the goniometer showing its capacities. (c) Schematic diagram of (b).

capacities of one of the sideband generators are shown schematically in Fig. 7(b). Fig. 7(c) is a schematic diagram of sideband generator Number 1.

It is demonstrated in another report[12] that the currents flowing in the loads $2Z_0$ of Fig. 7 are of two fre-

quencies, one higher and the other lower than the carrier frequency by the goniometer rotational frequency. Also, the Number-1 and Number-2 outputs consist only of sidebands that are 90 degrees out of phase at the modulation frequency.

Fig. 8 shows a view of the goniometer. Two rotors, each having four plates, are mounted one at each end of a longitudinally split rotor shaft to form one section of the sine-wave modulating capacitors. The rotor is driven at a speed of 1,800 rpm by means of a synchronous motor. The stators consist of five plates each, angularly

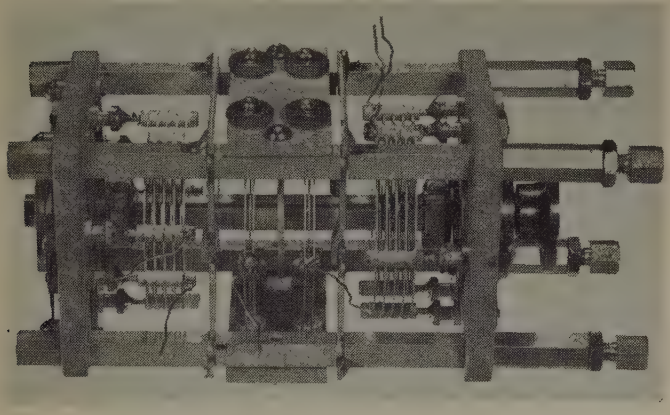

Fig. 8—View of goniometer with shield plates removed.

displaced by 90 degrees. The goniometer receives unmodulated rf power from the modulation eliminator and delivers two rf outputs having amplitudes proportional to the sine and cosine of the rotational angle of the goniometer. Transmission-line balance sections are required to permit operation of the balanced goniometer from the concentric coaxial cable. The medium for coupling the rf carrier from the modulation eliminator to the sine-wave modulating capacitors consists of a pair of rotor plates, located near the center of the rotor shaft and in close relation to a set of stators, each consisting of two plates. Faraday plates prevent capacitive coupling between the modulating stators and the coupling stators. A 360-degree dial with a vernier indicator makes it possible to determine the rotor position. The dial is adjusted to indicate zero when the rf power from one of the two output circuits is a minimum.

The input impedance to the goniometer is 40 to 60 ohms resistive, and is -10 to $+10$ ohms reactive, over the frequency range of 112 to 118 mc. The input is resonant at 115 mc. The rated rf power input is approximately 100 watts. Practice has shown that sufficient accuracy can be obtained if the null locations are 90 degrees apart ± 2 degrees, and the maxima are equal to within ± 5 per cent. The waveform should be a true sine wave with not more than 5-per cent harmonic distortion.

The 9.96-kc subcarrier, which is frequency modulated at 30 cps, is produced by an electromechanical subcarrier generator in the form of a tone wheel. The subcarrier generator and goniometers are driven on a common shaft. Teeth, machined into the periphery of the wheel, vary the magnetic field during rotation, producing a voltage in a pickup coil.

The output from the pickup coil is somewhat more than 0.6 mw into a 600-ohm load. An accurate phase adjustment over a range of ± 10 degrees is provided to permit exact adjustment of the phase of the reference phase signal with respect to the variable phase signal. This adjustment is accomplished by moving the yoke containing the pickup coil. The wheel provides a reference-phase signal that can be securely locked in step with the 30-cps variable-phase signal.

Modulation Eliminator

The modulation eliminator was developed to remove the 9.96-kc subcarrier modulation and voice modulation from that portion of the omnirange transmitter output which is fed to the goniometer. Provision is made for proportioning the transmitter output between the carrier and sideband antennas.

Referring to Fig. 9(a), let us imagine a bridge circuit made of three equal lengths of coaxial transmission line and a fourth length which is 180 electrical degrees longer than the others. The transmitter supplies power to the bridge at the junction marked A. The other three terminals of the bridge are connected to impedances Z_0, Z_1, and Z_2, which are normally pure resistances. Z_0 represents the load impedance presented by the capacity goniometer. The characteristic impedance of each of the transmission lines of the bridge is also Z_0. When $Z_2 = Z_1$, the bridge is balanced. A voltage E_s at point A sets up traveling waves in the branches ABC and ADC, which arrive at point C equal in magnitude and opposite

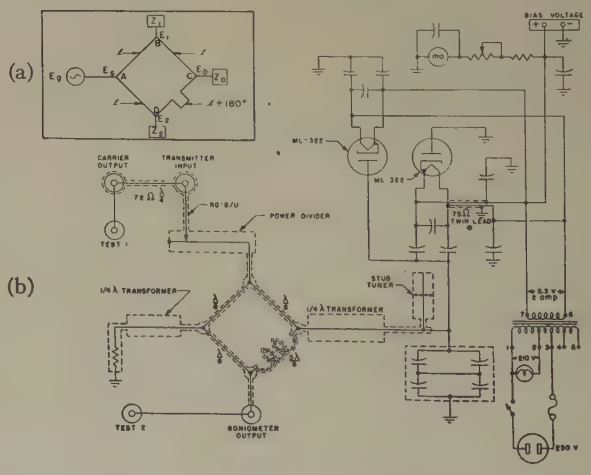

Fig. 9—Block diagram and schematic diagram of modulation eliminator.* 75Ω twin lead passes through stub tuner.

in phase. Thus, the voltage E_0 at point C is zero. When $Z_2 \neq Z_1$, the output voltage E_0 is not zero and power is delivered to the load. Fig. 9(b) shows a schematic diagram of the unit.

The oscillograms reproduced in Fig. 10 show the required performance of the modulation eliminator. All instantaneous voltages that exceed the modulation trough value are reduced to the trough value. This is accomplished by making both Z_1 and Z_2 resistive loads.

The value of Z_2 is a function of the modulation-eliminator input voltage. Point A, Fig. 10(a) corresponds to point A, Fig. 10(b); $Z_2 \neq Z_1$, therefore $E_0 \neq 0$. A short time later at point B, Fig. 12(a), $Z_2 = Z_1$ for the increment exceeding the trough value so that the instantaneous voltage output is that marked by point B, Fig. 10(b). Only that portion of the applied voltage which exceeds the trough value is cancelled at the output of the modulation eliminator.

A rear view of the modulation eliminator unit is shown in Fig. 11. Three of the four bridge arms are composed of solid dielectric lines, one-eighth wavelength long at 115 mc. The fourth arm of the bridge is also composed of solid dielectric line and is five-eighths wavelength long. The ML-322 diodes were especially designed for application in the modulation eliminator. The plate-cathode dc resistance is approximately 80 ohms in the forward direction and approaches infinity in the reverse direction. In order to obtain a low value of diode plate-cathode resistance for satisfactory operation of the circuit, the spacing between plate and cathode was held to about 0.010 inch. The plate-to-cathode capacity of the diodes is neutralized by a variable inductor, consisting of a short-circuited section of 70-ohm coaxial line.

The modulation eliminator is tested by observing the output of the unit on an oscilloscope, with the dc path

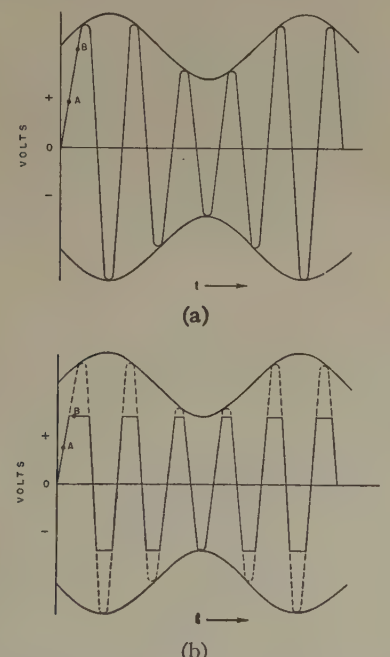

Fig. 10—(a) Voltage wave form at input to modulation eliminator. (b) Voltage wave form at output of modulation eliminator.

of the eliminator opened and then closed. When the dc path is open-circuited, the modulation eliminator is inactive so that the oscilloscope will display the modulation at the output of the transmitter. The dc path should then be closed to permit the unit to function and the envelope to be observed.

Typical power measurements of a modulation eliminator are

P_1 = power output of transmitter = 185 watts,

P_2 = power into eliminator = 58 watts,

P_3 = power output of eliminator = 13.1 watts,

P_4 = power into carrier antenna = 127 watts,

efficiency of modulation eliminator = P_3/P_2 = 22.6 per cent,

efficiency of system = P_4+P_3/P_1 = 75.7 per cent.

These data were obtained with carrier only from the transmitter. The modulation eliminator current was 56 ma. Since the unit is set to limit to the trough value of the amplitude-modulated envelope, the theoretical

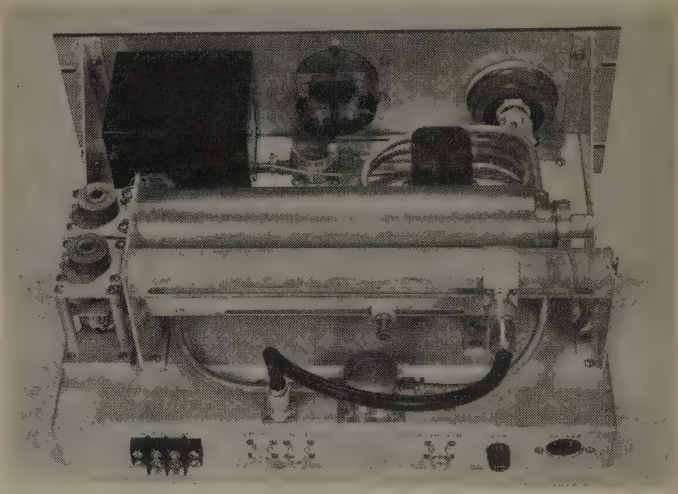

Fig. 11—Rear view of modulation eliminator.

maximum efficiency of the unit, as measured above with the 9.96-kc modulation off, is 67 per cent. This assumes that only the power represented by the voltage above the trough value is lost.

Transmitter and Audio Equipment

The omnirange transmitter[13] is designed to deliver an output of 200 watts of carrier in the frequency range 108 to 127 mc, capable of being modulated 100 per cent over the range 60 to 12,000 cps. The input circuit of the audio section provides the simultaneous transmission of three modulations, including voice, a 9.96-kc subcarrier, and a 1,020-cps tone for the purpose of station identification. The voice and subcarrier levels are each set to produce 30-per cent modulation of the carrier, while the tone signal is adjusted for 10-per cent modulation.

Monitor

Proper operation of the omnirange requires that the 30-cps signal of the variable-phase channel and the 30-cps signal of the reference-phase channel be exactly in phase at magnetic north. The monitor provides an alarm for a shift in the relative phase of the two 30-cps signals and for a decrease in amplitude of either the variable-phase or reference-phase signals.

[13] United States Dept. of Commerce, CAA, "Installation Instructions for VHF Omnirange," Federal Airways Manual of Operations IV-B-2-3. For further equipment instructions, refer also to "Description and Theory of VHF Omniranges," Federal Airways Manual of Operations IV-B-1-3.

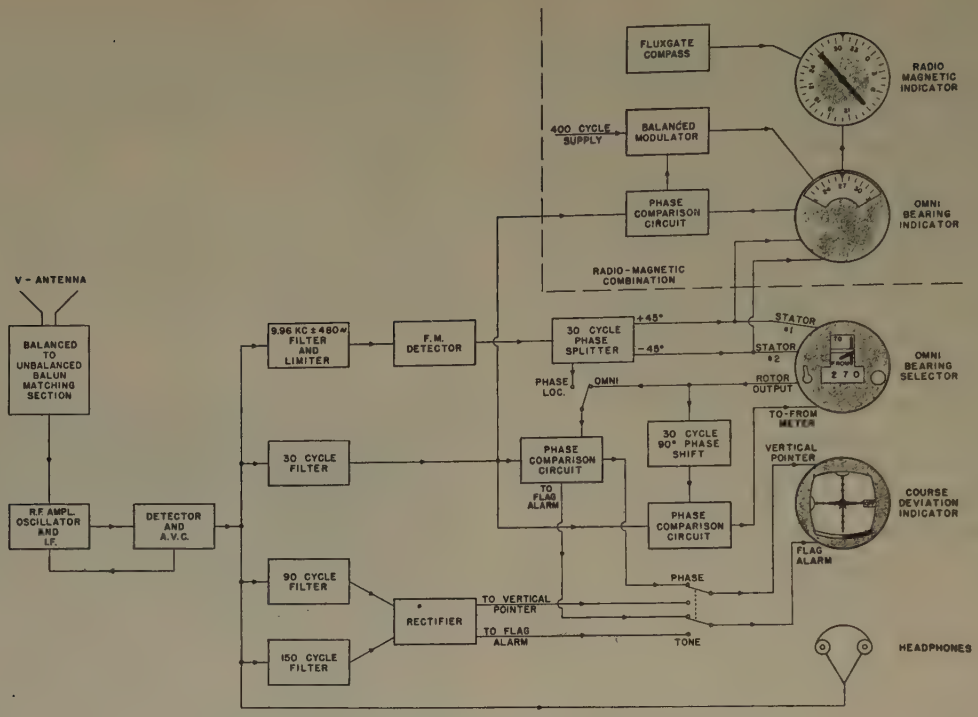

Fig. 12—Block diagram of vhf navigation receiver.

Station Identification

Identification of the omnirange is provided in two ways. One method utilizes an automatic voice-reproducing system for the benefit of aircraft pilots who are unfamiliar with the international Morse code. Station identification is transmitted approximately every 15 seconds by voice. The latter is recorded on a sound film which is moved continuously by a motor and a suitable arrangement of gears and pulleys so that the transmission at any desired interval between 10 and 20 seconds may be repeated.

A second method of station identification employs international Morse-code signals. A motor-driven keyer, with suitable cam and contact arrangement, transmits a series of dots and dashes in code to produce the identification letters assigned to the station.

Airborne Equipment

Fig. 12 is a block diagram of a typical navigation receiver which operates on the omnirange system and other navigational facilities, such as the two-course range, the 90–150-cps localizer, and the phase localizer.

General Performance Requirements

Some of the important requirements for the receiving equipment may be listed as follows:

1. The range courses and bearing will be shown in a visual manner.
2. It will be possible for the pilot to select rapidly any range course to or from the station.
3. The course-deviation indicator, when compared to a 360-degree indicator of similar size, will effectively amplify the course sensitivity in degrees by approximately five times.
4. An off-course condition will produce a direct voltage which can be used with automatic-pilot equipment and with a course-line computer.[14]
5. The receiving equipment will operate on localizers as well as on two-course and omnirange facilities.
6. The equipment will be capable of receiving voice communications from localizers, ranges, control towers, and communications stations.
7. It will be possible to provide an automatic indication of the magnetic bearing to the station.

Radio Frequency, Intermediate Frequency, and Detector

In general, the receivers are comprised of either a single, double, or triple superheterodyne rf section and an audio-converter section, consisting of filters and measuring circuits which connect to external navigational indicators. The frequency selection is accomplished by either manually tuning the rf-input circuits and simultaneously varying the frequency of a local oscillator, or by step tuning in conjunction with crystal control of the local oscillator. "Crystal-saver" circuits are used in step-tuned receivers to decrease the number of crystals required to provide 280 channels at 100-kc intervals over the frequency range of 108.1 to 136 mc. A delayed-action agc circuit is used to provide satisfactory operation of the measuring and indicating circuits. A high-level detector having excellent linearity is required to minimize cross-modulation components, including the unwanted components produced by propeller modulation. The detector output contains a combination of several signals. Suitable filters are necessary

[14] F. J. Gross and H. A. Kay, "Initial Flight Tests and Theory of an Experimental Parallel Course Computer," CAA Technical Development Report No. 83; September, 1948.

to separate these signals. The most important is the 30-cps low-pass filter which attenuates the unwanted signal caused by propeller modulation.

Phase-Shift Methods

The phase angle to be measured by the phase shifter is the one between the 30-cps E_{REF} signal, which has the same phase at all directions from the range station, and the 30-cps E_{VAR} signal, which has a phase that is a function of the magnetic bearing of the aircraft from the station. The E_{VAR} signal is in phase with the E_{REF} signal at the magnetic north of the station. As the aircraft is flown clockwise around the station, the phase of the E_{VAR} signal lags behind that of the E_{REF} signal by an amount equal to the magnetic bearing of the aircraft from the station.

As shown in Fig. 13(a), a quadrature circuit arrangement is used to provide the 90-degree phase difference required for the phase-shifter unit. If $R=1/\omega c$ at 30 cps, the phase of E_1' will be advanced 45 degrees and the phase of E_2' will be retarded 45 degrees from the phase of E. The stators of the phase-shifter unit will have voltages E_1 and E_2 of equal amplitude, but a phase difference of 90 degrees. The magnitude of the resultant rotor output is proportional to $(E_1^2 \sin^2\theta + E_2^2 \cos^2\theta)^{1/2} = E_R$, where θ = rotor angle in degrees. If $E_1 = E_2$, then E_R is constant for any phase angle. The phase angle of E_R is ϕ and $\phi = \tan^{-1} E_1 \sin\theta / E_2 \cos\theta$. For equal voltages, when $E_1 = E_2$, $\phi = \theta$. The error introduced by unequal voltages E_1 and E_2 will be the difference of ϕ and θ in degrees. The error caused by a 5-per cent decrease in E_2 is 1.4 degrees.

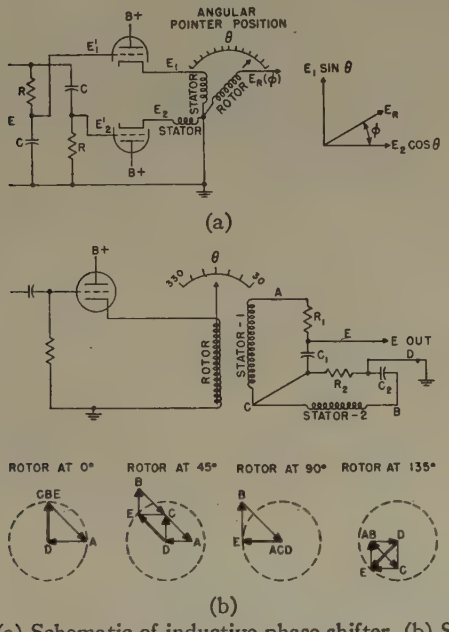

Fig. 13—(a) Schematic of inductive phase shifter. (b) Schematic of improved inductive-type phase shifter.

Errors may also be caused by variation in power-supply frequency at the transmitter. The quadrature relationship of voltages E_1' and E_2' remains unchanged, but their amplitudes will vary with a change in frequency. At a frequency of 31.5 cps, the difference in amplitude between E_1' and E_2' is 5.0 per cent, which will cause an error of 1.4 degrees.

The error caused by incorrect phasing of E_1 or E_2 by 1 degree is 1 degree.

In order that errors produced by the inductive-type phase shifters be held to a negligible value, the units are usually constructed by high-permeability laminated core material, similar to MU-metal, with a skewed rotor winding connected to a high-impedance load. The number of turns on the two stators must be the same and the two magnetic fields must be in exact quadrature.

Fig. 13(b) shows an improved method for using the inductive-type phase-shifter unit. In this method a single tube is used to feed the phase shifter and an rc circuit is connected across each stator. The use of a single tube insures greater reliability. The vector diagrams show the operation of this circuit arrangement.

In general, the inductive-type phase shifter provides the simplest means of obtaining accurate phase variation, which is directly proportional to the angular position of the rotor and provides constant output for all phase angles. The resistance-type phase shifter does not provide constant output, and is difficult to construct so that accurate phase variation proportional to the angular pointer position may be obtained.

Phase-Comparison Methods

The E_{VAR} signal from the phase-shifter unit, commonly known as the "omnibearing selector," is mixed with the E_{REF} signal in a phase-comparison circuit in which a zero-center instrument indicates the phase condition. Fig. 14 shows one type of phase-comparison circuit which has been used in navigation receivers. The circuit operates a dc instrument, which is a desirable feature since adequate damping is easily obtained and operation into automatic-pilot control systems is possible. From an inspection of the circuit diagram, Fig. 14(a), it is evident that current through rectifier G_1 causes point C to be positive with respect to point D. Current through rectifier G_2 causes point C to be nega-

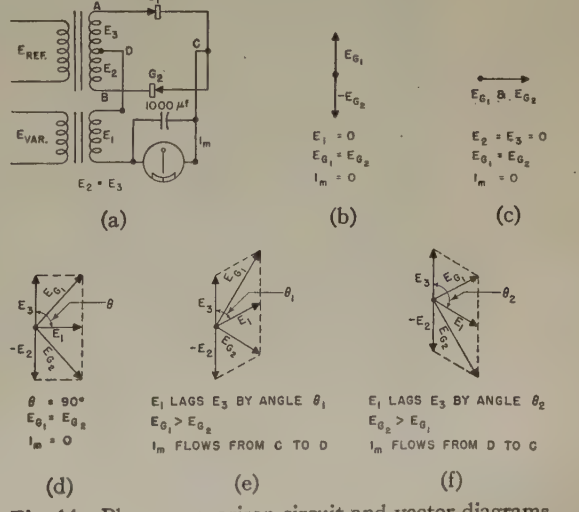

Fig. 14—Phase-comparison circuit and vector diagrams.

tive with respect to D. Other polarity conditions may be deduced as follows:

1. If the currents through rectifiers G_1 and G_2 are equal in magnitude, the net charge accumulated by the 1,000-μf capacitor, i.e., the sum of the currents through the indicator, is zero over each alternating-current cycle.

2. If the current through rectifier G_1 is greater than that through G_2, point C has a positive potential with respect to D. Indicator current I_m will flow from point C to D.

3. If the current through rectifier G_2 is greater than that through G_1, point D has a positive potential with respect to C, and indicator current I_m will flow from point D to C, causing the indicator pointer to deflect in a direction opposite to that in (2).

Vector diagrams b to f, inclusive, indicate phase relationships and indicator currents for various conditions. It has been shown that the resultant direct current through the indicator varies in amplitude and direction, depending on the phase relationship of the applied voltages. Since the instrument indicates average currents, the pointer deflection will be proportional to

$$KI = \left| [E_1^2 + E_2^2 + 2E_1E_2 \cos\theta]^{1/2} - [E_1^2 + E_2^2 - 2E_1E_2 \cos\theta]^{1/2} \right|,$$

where K is a constant. It follows that the current I changes sign as θ passes through 90 and 270 degrees, respectively. This action is desirable since it provides "sensing" to the instrument indication when used in the omnirange system. Sensing is defined here as the relative direction of motion of a course-deviation indicator needle, resulting from the departure of an aircraft in a definite direction from the desired flight path. The fact that there are two phase angles where the course-deviation indicator current is zero makes it necessary that both phase conditions be resolved and indicated. One method of doing this is shown in Fig. 15. The method used has a second phase-comparison circuit

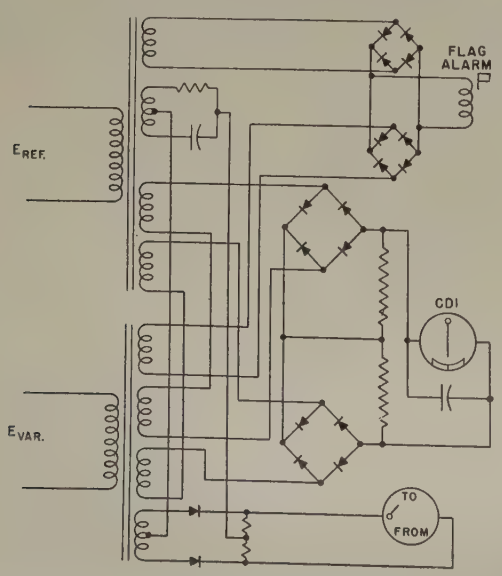

Fig. 15—Phase-comparison circuit with flag alarm and to-from indicator.

operating at a 90-degree phase displacement from the first phase-comparison circuit, together with an instrument to provide the indication desired. The sensing action of this indication is used in the omnirange system to show whether the numerical reading of the omnibearing selector for an on-course indication of the course-deviation indicator represents the bearing to or from the station. This instrument is commonly referred to as a "to-from indicator." In the circuit shown a small portion of the E_{VAR} and E_{REF} voltages is rectified and fed to the course-deviation indicator to operate the flag-alarm movement, which is now included in the latest type of indicators.

Omnibearing Indicators

To provide an automatic and continuous indication of the magnetic bearing to the omnirange station requires additional circuits and instrumentation. Fig. 16

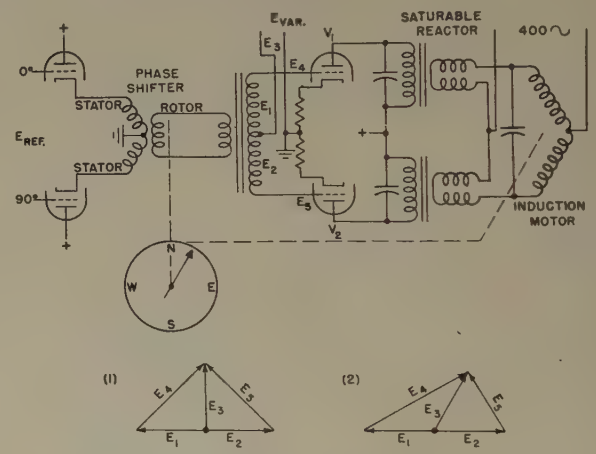

Fig. 16—Omnibearing indicator circuit.

shows a method of providing an automatic phase indicator. As shown in the diagram, the E_{REF} signal is split into quadrature components and fed to the stators of a phase-shifter unit. The rotor output is fed into a servo amplifier, where it is combined with the E_{VAR} signal in a phase-detector circuit. The phase-detector circuit consists of two tubes which are connected to two saturable reactors which, in turn, are connected to a balanced two-phase induction motor. When an unbalance exists, the motor rotates and, by means of a gear arrangement, turns the rotor of the phase-shifter unit to the point where a balanced condition exists. Vector diagram 1 shows the condition when the circuit is balanced and vector diagram 2 shows the condition when the circuit is unbalanced. Voltages E_4 and E_5 in diagram 2 are of different amplitude and, as a result, the currents through the saturable reactors are of different amplitudes. This creates an unbalance in the motor circuit, causing it to rotate and turn the rotor of the phase shifter to a position where a balanced condition again exists.

Radio-Magnetic Indicator

The navigation indicators described thus far provide omnirange bearing and course information independent

of the aircraft heading. An instrument has been developed that is known as the "radio-magnetic indicator" (RMI) which, when used in combination with the omnirange and flux gate or gyrosyn systems, will automatically show both the heading and the magnetic bearing of the aircraft to the station. The instrument is, in effect, an omnibearing indicator, as previously described, together with a servo unit operating from the flux gate or gyrosyn system. The complete omnibearing indicator rotates to a position determined by the heading of the aircraft. The pointer of the instrument will indicate the station, and this action is analogous to that of the 360-degree indicators used with low-frequency automatic radio compasses. Fig. 17 shows the circuits of this instrument.

Omnirange Instrumentation

An example of omnirange instrumentation, using the instruments described, is illustrated in Fig. 18. In the example shown, the aircraft is south of the station and flying a course to the station and beyond. The omnibearing selector is set for a course of 350 degrees. When flying this course to the station, the sensing is such that, when the needle of the course-deviation indicator deflects from the zero center, it is necessary to fly the aircraft in the same direction in which the needle deflects so that the needle can return to the zero center; i.e., if the aircraft is flown to the left of the course, the needle will deflect to the right. To return to the course so that the needle will read zero, the aircraft must be flown toward the right.

For the 350-degree omnibearing course to the station, the magnetic compass in the aircraft reads 350 degrees also, neglecting instrument errors and the crab angle. As the aircraft passes directly over the station, the to-from and course-deviation indicators will show several rapid fluctuations. After passing the station and continuing on the same course, the course-deviation indicator will show on-course and have the same sensing as when approaching the station; but the to-from indicator will point to the word "from," indicating that the magnetic bearing of the aircraft from the station is 350 degrees. The magnetic compass will continue to read 350 degrees since no change of heading has been made.

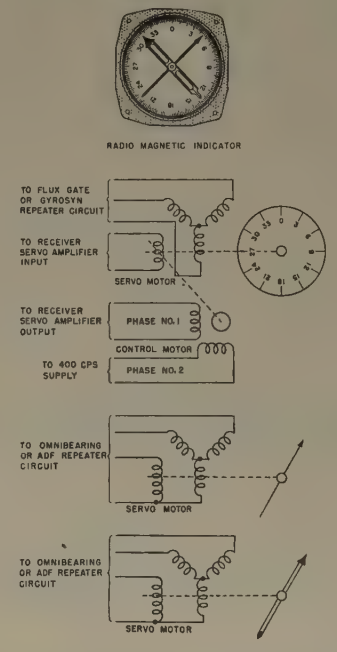

Fig. 17—Radio magnetic-indicator circuit diagram.

If, after continuing on this course, the aircraft makes a turn of 180 degrees to fly the same course back to the station, the course-deviation indicator and to-from indicator will not change, except for small variations due to banking, and the like. However, the magnetic com-

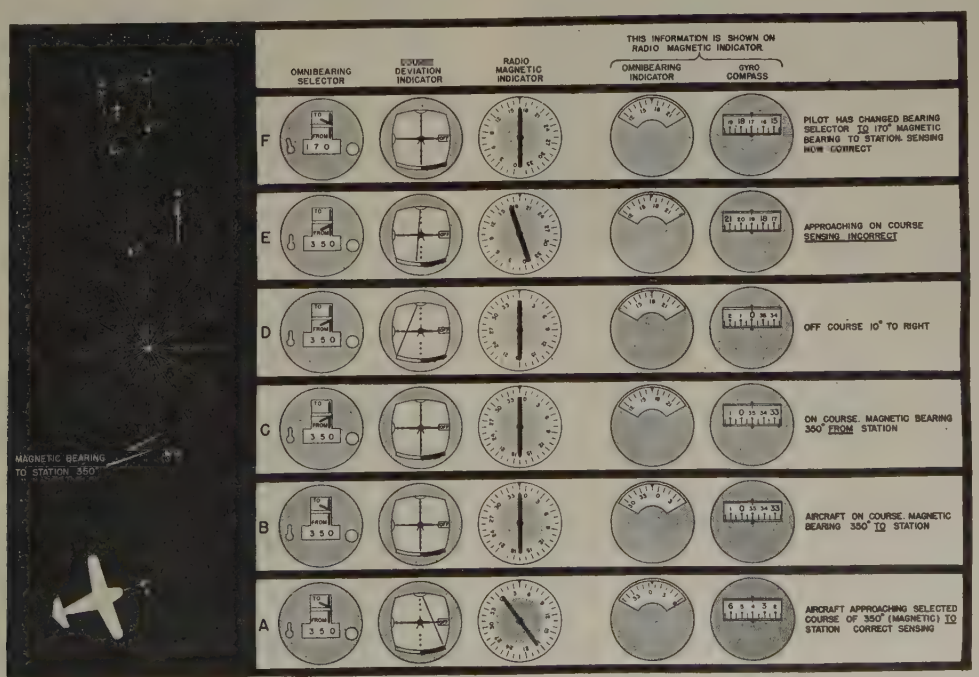
OMNIBEARING SELECTOR
DEVIATION INDICATOR
RADIO MAGNETIC INDICATOR
THIS INFORMATION IS SHOWN ON RADIO MAGNETIC INDICATOR
OMNIBEARING INDICATOR
GYRO COMPASS
F
PILOT HAS CHANGED BEARING SELECTOR TO 170° MAGNETIC BEARING TO STATION. SENSING NOW CORRECT
E
APPROACHING ON COURSE SENSING INCORRECT
D
OFF COURSE 10° TO RIGHT
C
ON COURSE. MAGNETIC BEARING 350° FROM STATION
B
AIRCRAFT ON COURSE. MAGNETIC BEARING 350° TO STATION
A
AIRCRAFT APPROACHING SELECTED COURSE OF 350° (MAGNETIC) TO STATION CORRECT SENSING
MAGNETIC BEARING TO STATION 350°

Fig. 18—Omnirange instrumentation combined with magnetic information.

pass will now read 170 degrees and the sensing will be reversed. Therefore, it is necessary to change the omnibearing selector to show a course of 170 degrees to the station. This will cause the to-from indicator to point to the word "to" and show the correct sensing of the course-deviation indicator. It should be pointed out that, under the correct conditions of flying omnirange courses, the omnibearing selector should read approximately the same as the magnetic compass.

Fig. 19 illustrates how the omnirange may be used

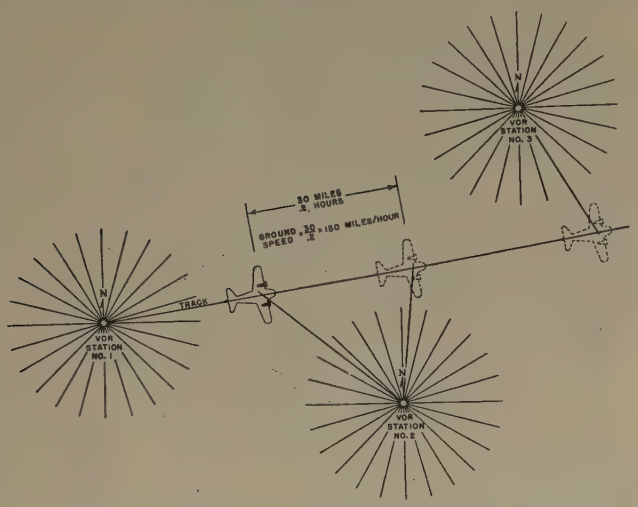

Fig. 19—Omnirange utilization for determining position and ground speed.

to provide position and ground-speed information for the pilot. The intersection of the two lines corresponding to the bearings observed from any two stations gives the position of the aircraft. A second similar observation made sometime later will provide information that can

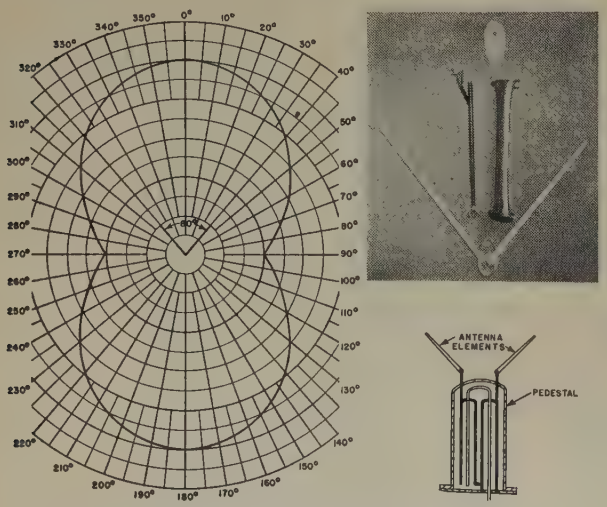

Fig. 20—Calculated field pattern in horizontal plane, balun arrangement and component parts.

be used to determine the actual ground speed of the aircraft.

Aircraft Antenna

Since the signal radiated from the omnirange station is horizontally polarized, it is necessary that the aircraft antenna be designed to receive horizontally polarized signals. One type of antenna which has been used extensively for reception in the frequency band of 108 to 122 mc is the V-type antenna, the parts of which are illustrated in Fig. 20. The diagram in this illustration shows the method used to connect a balanced antenna to a coaxial transmission cable. The impedance matching between the antenna, which has been determined to have a radiation resistance of approximately 33 ohms, and the standard 52-ohm RG 8/U cable, is accomplished by using a one-quarter wavelength balun section having a 42-ohms impedance. Also shown in this figure is a calculated field pattern for an antenna having one-quarter wavelength elements and an apex angle of 80 degrees.

The aircraft antenna is usually installed either on top of the fuselage behind the pilot's compartment or on the tail structure, as shown in Fig. 21. For this reason,

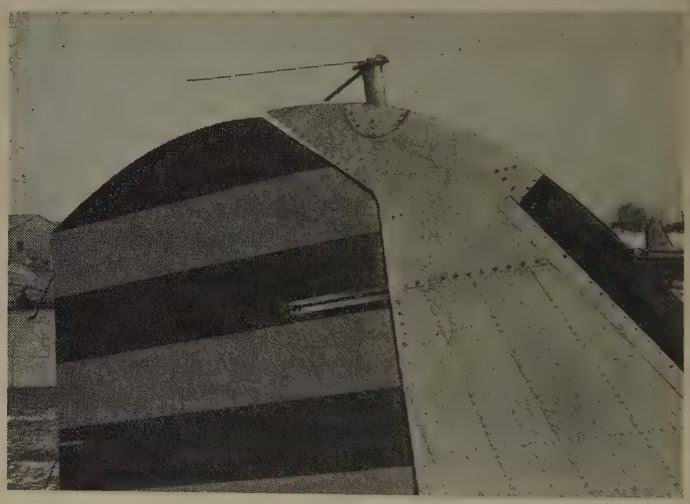

Fig. 21—Antenna mounted on vertical stabilizer.

it is necessary to make antenna measurements over a ground plane and also in free space. Standing-wave ratio measurements of the V-type antenna, between 108 and 122 mc for free-space conditions, showed a minimum of 1.3 and a maximum of 3.0. Similar measurements made over a ground plane showed a standing-wave ratio minimum of 1.4 and a maximum of 3.0.

Receivers and Their Characteristics

The first commercial omnirange-receiving equipment was developed in 1946 by the Aircraft Radio Corporation. The receiver is an eight-tube superheterodyne, having continuously variable tuning over the frequency range of 108 to 135 mc.

Fig. 22 shows the Type 51R-1 airline-type equipment developed by the Collins Radio Company. The receiver is a double superheterodyne which may be tuned from 108 to 135 mc in 100-kc steps by a remotely controlled mechanism, called an "autopositioner." Bearing information is provided by a complete set of instru-

ments, including a frequency selector, radio-magnetic indicator, omnibearing indicator, course-deviation indicator with flag alarm, and an omnibearing selector with a to-from meter.

Late in 1947 a contract was entered into with the National Aeronautical Corporation to develop a low-cost, lightweight navigation receiver for private-flyer use. The receiver supplied on this contrast is a seven-tube superheterodyne, having continuously variable tuning over the frequency range of 108 to 122 mc. Bearing information is provided by a tapped-potentiometer-type bearing selector, a to-from indicator, and a single needle-type course-deviation indicator. The total weight of the unit, exclusive of cables, is 15 pounds, and provision is made for adding a vhf-transmitter unit to this equipment.

Omnirange Operational Characteristics

Siting of Ground Stations

The vhf omnirange requires reasonably good sites. Surfaces formed by objects, such as trees, buildings,

Fig. 22—Collins-type 51R-1 navigation receiver.

wires, hills, and the like, re-radiate or attenuate energy from the antenna system, causing course-deviation indicator fluctuations.[15] Course errors result if the fluctuations are very slow. A large number of installations offering a variety of siting conditions have been studied to determine siting requirements for satisfactory operation of the omnirange.

To briefly summarize siting requirements, it has been found that the site must be located on flat terrain or on top of a knoll that has uniform contours for a distance of 1,500 feet and is cleared of all obstacles, such as large buildings, woods, power lines, and the like, capable of serious re-radiation to a distance of 1,000 feet. In addition, all obstacles within 2,000 feet should subtend an angle in the vertical plane of less than 2.0 degrees, and the power line to the station should be installed underground for a distance of 750 feet.

[15] J. M. Lee, R. G. Pamler, and B. M. Lahr, "An Investigation to Determine the Characteristics of Horizontal and Vertical Polarization for Very High-Frequency Two-Course Visual Radio Ranges," CAA Technical Development Report No. 58; July, 1947.

Distance-Range and Course-Deviation Indicator Fluctuations

Flight tests have confirmed the fact that vhf-navigational facilities are limited to a usable distance range approximating line-of-sight. Certain rare cases have been reported where the distance range was found to be much greater than line-of-sight for a short time. However, this phenomenon has not been experienced at the experimental station.

Fig. 23 shows reproductions of flight recordings of the course-deviation indicator deflections, made when an airplane flew a straight ground track from an omnirange station and flew over the station at 10,000-foot altitude. The variation in course-deviation sensitivity[16]

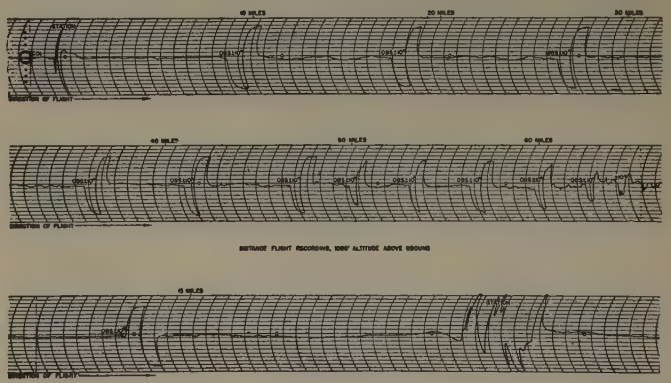

Fig. 23—Recordings of course-deviation indicator at two altitudes, Radial flight across VOR 10,000-foot altitude above ground. CDI-course-deviation indicator. OBS-omnibearing selector. Type-51R receiver, tail V-109 antenna, and C47-type aircraft.

is indicated by the deflections on the recording, for adjustments of the omnibearing selector, of ±10 degrees. It will be observed that the course-deviation indicator fluctuations are very small in amplitude on this recording. Course fluctuations are caused mainly by poor site conditions at the range stations; consequently, some stations will show more course fluctuations than others. Although a 20-degree course-deviation sensitivity was used for these tests, flight experience has shown that a 30-degree course-deviation sensitivity is more satisfactory from the pilot's viewpoint. The site conditions at this range station are considered good. The course fluctuations shown on the recording made at 10,000 feet indicate a cone area directly over the station where the bearing information is not accurate. However, these violent fluctuations are such that they provide a positive-position indication of the station.

Course Stability

The prototype vhf omnirange, which has been operating for more than 3 years, has been monitored continuously. Faults have occurred at the station usually be-

[16] Course-deviation sensitivity is defined as the total number of degrees of adjustment of the omnibearing selector required to cause the pointer of the course-deviation indicator to move from full-scale left to full-scale right.

cause of a tube failure; this results, for example, in low power output with very high 9.96-kc modulation, at which time a course measurement by the monitor was not possible because of low signal levels. However, during normal operation the course monitor has indicated a maximum of 1-degree deviation from the correct reading. Fig. 24 shows a set of monitor readings which were taken over a period of 30 days. The monitor antenna is located on a line, which is magnetic north of the station and where the two figure-of-eight patterns are of equal magnitude, so that any change in the relative sizes of the patterns will be observed. Courses in other directions

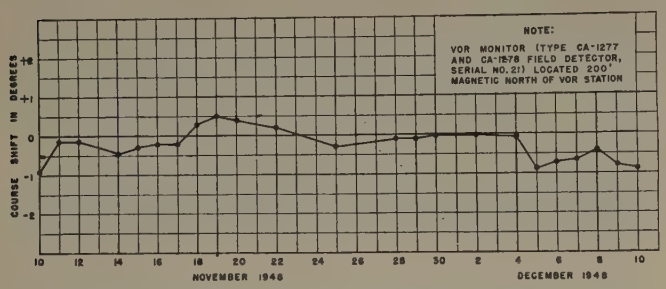
NOTE:
VOR MONITOR (TYPE CA-1277 AND CA-1278 FIELD DETECTOR, SERIAL NO. 21) LOCATED 200' MAGNETIC NORTH OF VOR STATION
COURSE SHIFT IN DEGREES
+2
+1
0
-1
-2
10 12 14 16 18 20 22 24 26 28 30 2 4 6 8 10
NOVEMBER 1948
DECEMBER 1948

Fig. 24—Course shift as indicated by the VOR monitor versus time.

have been checked either by a theodolite flight calibration of the facility or by turning the antenna array through 360 degrees. Stability comparable to that indicated at the monitor was found.

Flight Calibration

The flight calibration of an omnirange system has been described in a previously published report,[17] and only a brief description of the method used will be given here.

The method used consists of recording the voltage applied to the course-deviation indicator as the aircraft circles the station at a radius of 6 to 15 miles. The omnibearing selector is advanced in 10-degree steps to keep the course-deviation indicator on scale and to provide a recording whereby the indicated magnetic bearing from the range station may be obtained. The indicated bearing is compared with the magnetic bearing, as measured by a theodolite operated on the ground at the range station.

Polarization Errors

Tests have demonstrated that, while the omnirange antenna array radiates horizontally polarized energy, currents induced on the surface of the pedestals supporting the sideband loops radiate energy that is vertically polarized. This vertically polarized energy will produce omnibearing indications which are at quadrature with true bearing information, and errors caused by such radiation are termed "polarization errors."

If an aircraft equipped with a navigation receiver flies over a fixed ground-check point at a number of different headings, the indicated omnibearing may be found to vary with the heading. The aircraft, when over the ground-check point, has only one correct omnibearing, and it is independent of heading; consequently, the change in the omnibearing with heading is one form of polarization error, referred to as "push-pull error." The term comes from early navigational-aids work, where the course was observed to be pushed ahead of the aircraft, or pulled toward it when flying across the course. The aircraft receives the signal from the horizontally polarized wave primarily; however, as the heading is changed, the ratio of vertically to horizontally polarized pickup varies, producing different omnibearing indications when the aircraft is over a ground-check point. Polarization errors, in general, vary with the type of aircraft and with the location of the receiving antenna on the aircraft. Table I shows how the push-pull error may vary with heading.

TABLE I

PUSH-PULL POLARIZATION ERROR TESTS IN A DC-3 AIRCRAFT WITH A RECEIVING ANTENNA-LOCATED JUST BEHIND THE ASTRODOME
(*Aircraft Located at 0-degree Azimuth*)

	Azimuth Selector Readings for the Following Headings							Maximum Overall Error
Headings (Degrees)	0	90	135	180	225	270	315	
Pedestals Exposed	−1.5	0	−3.0	−2.5	+1.0	−3.0	−6.0	7.0
Uskon Cloth Around Pedestals	−1.0	0	−1.5	−1.6	−0.5	−1.0	−1.0	1.6

Many attempts have been made to reduce the polarization error. The most successful of these was the placement of Uskon cloth around the pedestals, as a group, and the cloth was insulated from the pedestals by wooden strips. This cloth has an rf resistance of about 377 ohms per square. Table I lists the indicated bearings observed when the vertically polarized-field effect was reduced by a factor of approximately four when Uskon cloth was used.

Another form of polarization error occurs when an aircraft is banking or turning. Under these conditions, the indicated omnibearing may change even though its direction from the station is unchanged. This type of polarization error is generally referred to as "attitude error." Flight tests made before and after the Uskon cloth was installed showed that its installation decreased the attitude errors. Table II lists the maximum errors observed in 360-degree turns, at a 30-degree bank, dur-

TABLE II

ATTITUDE ERROR AT VARIOUS DISTANCES WITH AND WITHOUT CLOTH INSTALLED

Distance From Station (Miles)	Maximum Error	
	With Cloth Installed (Degrees)	Without Cloth Installed (Degrees)
13.75	±1.5	±2.25
23	±1.75	±3.4
38	±2.1	±3.1

[17] T. S. Wonnell, "Flight Calibration of VHF Omnirange System," Technical Development Report No. 69; July, 1947.

ing a flight test in a DC-3 airplane. The tests were conducted at various distances from the station, and ARC-15 receiving equipment and the tail V antenna were used. Table III shows a comparison of the attitude errors noted when using the tail V antenna and the forward V antenna. These tests were also conducted in a DC-3 airplane, using ARC-15 receiving equipment. The Uskon cloth was in place during both tests.

TABLE III

COMPARISON OF ATTITUDE ERRORS WHEN USING TAIL V ANTENNA AND FORWARD V ANTENNA

Distance From Station (Miles)	Maximum Error	
	Tail V Antenna (Degrees)	Forward V Antenna (Degrees)
13.75	±1.75	±2.0
23	±1.86	±1.8
38	±1.75	±1.25

Propeller Modulation

In the early stage of development of the omnirange system it was observed that aircraft propellers caused the received signals to modulate. As a result of the modulation produced by the propellers, the course-deviation indicator will oscillate at an amplitude and rate depending on the amplitude and rate of the propeller modulation. Flight tests were conducted on omnirange systems using 30, 40, and 60 cps for the variable- and reference-phase signals. It was determined that a frequency of 30 cps would be the most desirable since the cruising propeller rpm of all known aircraft produces a propeller-modulation frequency higher than 30 cps. Simultaneous flight recordings of omnirange courses, using a 30-cps range system and a 60-cps range system, are shown in Fig. 25. The engine speed was adjusted to

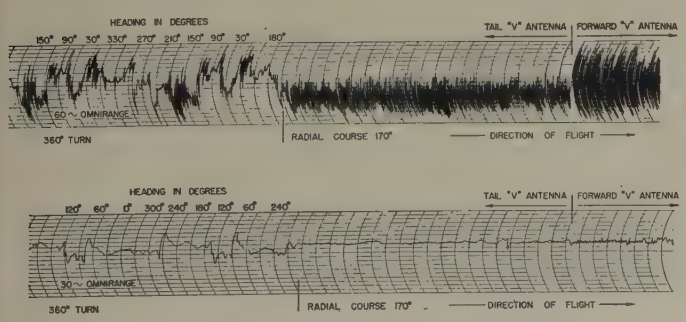

Fig. 25—Comparison of course-deviation indicator fluctuations for 30- and 60-cps omniranges. NC-182 (DC-3/c-47) 2,130 rpm both engines flight altitude 3,000 feet. Absolute distance from ranges 5 to 10 miles. Receiver 30~omnireceiver Number 7. Limiter in 10-kc reference channel. Wein bridge in variable channel. 60~omnireceiver number 6. Antennas: tail V coaxial type; forward V delta type. 60-omnitransmitter 125 mc. 30~omnitransmitter 114.3 mc.

provide a propeller modulation of approximately 60 cps. It will be observed that the 30-cps range is free of variations caused by propeller modulation when the tail V antenna is used, and shows only a small variation when the forward V antenna, which is located near the propellers, is used. Recent improvements in navigation-receiver design provide further improvements in freedom from propeller-modulation effects.

Interference between Stations

Flight tests have been conducted to determine the interference characteristics existing between omnirange stations operating on the same carrier frequency and on adjacent frequency channels of 100-kc separation. ARC-15 navigation receivers were used for all tests.

To determine the interference area between two omnirange stations operating on the same frequency, those at Allentown, Pa. and Raleigh, N. C., separated by 383 miles, were both tuned to 117.5 mc. The area between the two stations was flown at various altitudes from 12,000 to 20,000 feet, and fixes were obtained by means of the MEW radar installation located at the Washington National Airport. The information obtained in the flight tests is shown in Fig. 26. The mini-

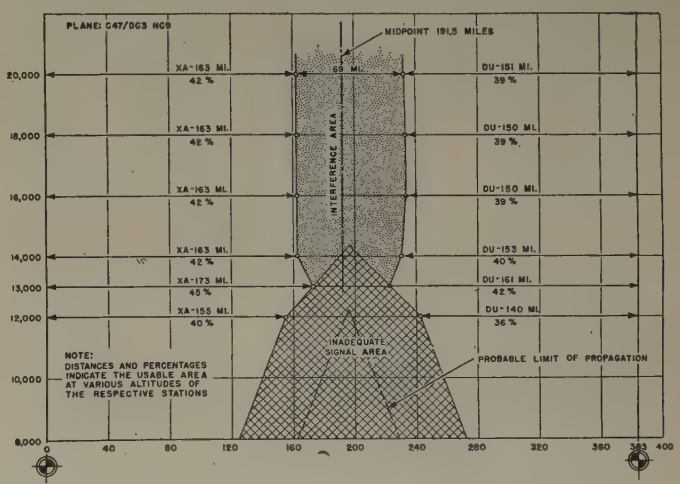

Fig. 26—Interference characteristics of two omnirange facilities operating on the same frequency. Distance in miles XA-117.5 mc. Allentown, Pa. VOR elev. 670-feet MSL. DU-117.5 mc. Raleigh, NC. VOR elev. 403-feet MSL.

mum interference altitude appears to be approximately 14,500 feet since below this level the limiting factor is inadequate signal strength. Above 14,500 feet, the interference area consists of a combination of severe audio heterodyning and variations of the course-deviation indicator. Summarizing, when two omnirange stations are operated on the same frequency, the useful distance range at high altitudes is approximately 40 per cent of the spacing between the stations.

The investigation of adjacent frequency-channel interference was made using omnirange stations located at Raleigh, N. C. and Spartanburg, S. C. The Raleigh station was operated on a frequency of 117.4 mc, and the Spartanburg station on a frequency of 117.5 mc. The geographical separation was 192 miles. The information obtained in these flight tests (see Fig. 27) indicates that from approximately 60 per cent at 6,000 feet to 75 per cent at 13,000 feet of the total distance is usable without interference. In this test it is important to note that the results obtained are dependent to a great extent on the selectivity characteristics of the receiving equipment.

The use of an airline-type receiver, such as the Collins 51R, would have provided vastly different results in the usable distance range.

Additional information concerning the co-channel interference was obtained by laboratory tests, and is shown in Fig. 28. For these tests, simulated omnirange signals from two signal generators were fed to an airline-type receiver, and the ratio of the rf signal levels was varied. The phase of the variable-phase signals was adjusted to cause the greatest interference on the indicators.

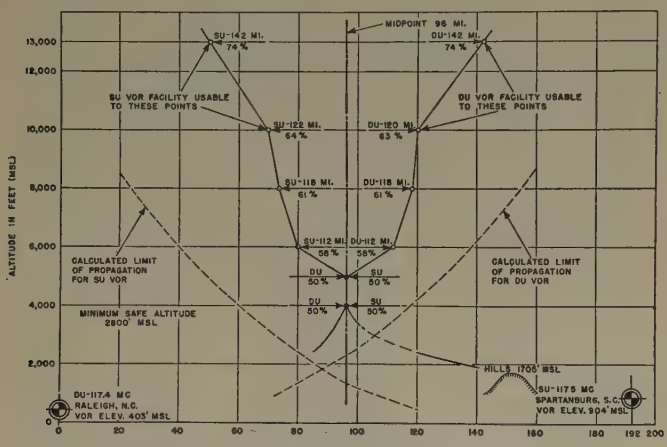

Fig. 27—Adjacent channel interference characteristics of two omnirange facilities. Distance in miles.

Power-Frequency Variation

In some remote sections of the country, where it may not be possible to obtain a standard commercial source of 60-cps power, it may be necessary to operate the station from local power or, perhaps, to utilize the emergency supply which is standard equipment at all CAA

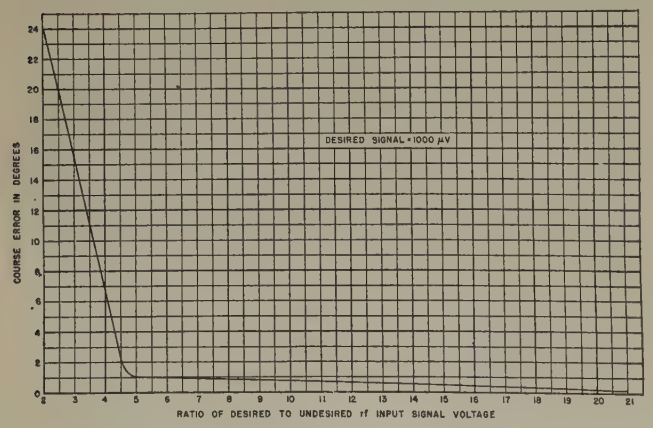

Fig. 28—Course error versus ratio of desired to undesired signal strength.

radio-range stations. In some cases these sources of power do not maintain a constant frequency of 60 cps, and deviations as much as ±2 cps may be experienced. At those stations where the power-supply frequency variation exceeds ±0.6 cps, a stabilized 60-cps tuning fork-type generator and amplifier will be installed to supply power to the goniometer and subcarrier equipment.

Conclusions

As a result of several years of study and development, in addition to 4 years of operation of omnirange facilities, the following general conclusions have been reached:

1. The theoretical aspects of the phase-comparison system for omnirange operation are sound.
2. Horizontal rather than vertical polarization provides steadier course indications.
3. A transmitter power rating of 200 watts is adequate for line-of-sight operation to a distance of approximately 200 miles at an altitude of 20,000 feet, 100 miles at 5,000 feet, 63 miles at 2,000 feet, and 45 miles at 1,000 feet.
4. An accuracy of approximately ±1.5 degrees may be realized on radial courses where the sites are free of serious reflecting objects. The accuracy figure is for the complete omnirange system, receivers, plus ground equipment.
5. Sites located on flat terrain with all obstacles, such as large buildings, woods, power lines, and the like, cleared to 1,000 feet, and all obstacles within 2,000 feet subtending a vertical angle of less than 2 degrees have proven to be satisfactory. Nearby hills, higher than the site, reduce the distance range on radials passing over the hills.
6. Generation of sidebands by means of a rotating capacity goniometer was found more stable and reliable than methods using electronic sideband generators.
7. For unattended operation, a monitor must be included as part of the ground equipment. This provides the maintenance personnel with continuous knowledge as to the status of the facility and with a useful tool for corrective maintenance. The monitor will show up a fault as soon as it occurs, and will further insure that the pilot receives only correct information.
8. Either automatic or manually operated indicating devices may be used to provide the pilot with navigational information. The latter type, however, defines the range course more accurately.
9. Modulation factors of 30 per cent each are satisfactory for the reference and variable-phase signals, and the remaining 40 per cent is adequate for voice modulation and 1,020-cps tone identification.
10. Propeller modulation of received signals interferes with the omnirange courses under certain critical conditions of heading and propeller speed. A reduction in frequency from 60 to 30 cps, for the reference and variable-phase signals, has minimized this interference.

As a result of this development and operational experience, the vhf omnirange has been adopted as one of the basic elements of the Common-Civil-Military System, Transition Program, as recommended by the Radio Technical Commission for Aeronautics, Special Committee 31.

Information Theory and the Design of Radar Receivers*

PHILIP M. WOODWARD†

Summary—**The paper deals with the problem, frequently encountered in radar, of extracting simple numerical information from a noisy waveform. It is suggested that the only ideal way of doing this is to use the principle of inverse probability and convert the waveform into a probability distribution for the quantity sought. The method is applied to the problem of determining the time delay of a periodically modulated rf waveform in the presence of white Gaussian noise when the undelayed waveform without noise is exactly known. As a result, the matched predetection filter of Van Vleck and Middleton is automatically specified, and the theory of ideal detection is briefly indicated.**

I. Introduction

THE OBJECT of this paper is to outline, in terms of a somewhat idealized example, a mathematical method by which a theoretically ideal radar receiver may always be specified in principle. It was for some time customary to regard signal-to-noise ratio as an all-important quantity in receiver design. Efforts were made to ensure that as high a ratio as ideally possible was obtained at the output. This seems now to be a mistaken philosophy, since signal-to-noise ratio does not measure information, and is something which can often be artificially enhanced by passing the waveform through a nonlinear device which does not alter the information content at all. The present method deals, not with signal-to-noise ratio, nor even with quantities of information, but with the information itself.

In radar, we have to answer such questions as whether a target is present or absent, what its range is, whether it is moving, and so on. If we attempt to design a receiver which would answer any or all of such questions exactly, we are attempting the impossible, because of the noise which must inevitably introduce false indications. But if we demand, on every occasion, an automatic assessment of the relative probabilities of all possible answers, we are being completely realistic and no receiving device can possibly do better. The present paper shows how this idea works out in one rather familiar problem—that of determining the time delay of a periodic waveform of known shape and amplitude. This amounts, in radar, to determining the range of a stationary target known to be present and giving an echo of known strength, and is obviously an artificial problem. But it suffices to illustrate the method, and is not altogether without practical interest. The quantity of range information latent in such a radar waveform has been evaluated elsewhere[1] without reference to any actual method of extracting it. Here the emphasis is on designing the ideal receiver rather than on evaluating its actual performance.

The whole of the present approach is based on the principle of inverse probability briefly summarized in the following section. There is nothing new in this principle, but in spite of the growing application of probability theory to such problems as arise in radar, as for instance by Kaplan and McFall,[2] there does not seem to have been a systematic attempt to apply inverse probability. The necessity for doing so becomes quite apparent, once the foundations of modern communication theory[3] have been studied. The present paper may perhaps help to "set the ball rolling," for the method can be applied to a very wide variety of radar problems.

II. The Principle of Inverse Probability and the Information Function

A "direct" probability describes the chance of an event happening on a given hypothesis, but if the event has actually happened and there are various hypotheses which would explain it, one is faced with a problem of inverse probability. Prior to the event, the various hypotheses may not have seemed equally probable, and such previous knowledge is expressed in terms of the *a priori* probabilities of the hypotheses. After the event, which will usually be an experimental observation specifically performed to test the hypotheses, their relative probabilities may become changed. The principle of inverse probability expresses the *a posteriori* probabilities in terms of the corresponding *a priori* ones, by utilizing the probabilities that the actual observation would have been obtained if each hypothesis in turn had been true. It is valid only when the hypotheses are mutually exclusive and exhaustive.

Let H_1H_2, and so on, denote the hypotheses,

$P(H_n)$	the *a priori* probability of H_n
$P(Ob\|H_n)$	the probability of the observation if H_n were true
$P(H_n\|Ob)$	the *a posteriori* probability of H_n after the observation is known.

The theorem[4] may then be written briefly in the form

* Decimal classification: R537.13. Original manuscript received by the Institute, June 23, 1950; revised manuscript received, March 9, 1951. The present paper is a revised version of the paper originally communicated to the Institute by G. G. Macfarlane, under the title "The decoding of radar information."

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[1] P. M. Woodward and I. L. Davies, "A theory of radar information," *Phil. Mag.*, ser. 7, vol. 41, p. 1001; October, 1950.

[2] S. M. Kaplan and R. W. McFall, "The statistical properties of noise applied to radar range performance," PROC. I.R.E., vol. 39, pp. 56–60; January, 1951.

[3] C. E. Shannon, "A mathematical theory of communication," *Bell Sys. Tech. Jour.*, vol. 27, pp. 379, 623; July and October, 1948.

[4] Harold Jeffreys, "Theory of Probability," chap. I; Oxford University Press; 1939.

$$P(H_n \mid Ob) \propto P(H_n)P(Ob \mid H_n). \quad (1)$$

In the present application, the hypotheses are all the possible delay times of a given periodic waveform, and the "observation" is simply the given waveform delayed an unknown amount, and with white Gaussian noise added to it. We shall call this the "received waveform," but it is not the output from a receiver because this would prejudge the whole question. It is the waveform as it enters the receiving system, including any noise which the receiver itself may subsequently introduce. The *a priori* probabilities of the hypotheses will form a continuous probability density distribution for the unknown delay time τ, and for simplicity this distribution will be taken uniform over an interval equal to one period of the waveform. In other words, we take all inherently unambiguous delay times to be equally likely *a priori*, though any other prior knowledge can subsequently be inserted in the theory.

The best that any receiver can do is to form the *a posteriori* distribution of probability for τ, from the received waveform. This distribution is the actual information sought, and is most conveniently handled in logarithmic form. We shall call its logarithm the "information function" and denote it by $Q(\tau)$. Equation (1) may now be written

$$Q(\tau) = \log P(Ob \mid \tau) + \text{constant}, \quad (2)$$

where $P(Ob|\tau)$ denotes the probability density for the received waveform on the hypothesis τ. The constant term is merely the logarithm of the normalizing factor for the *a posteriori* distribution. It serves no useful purpose and is in the future omitted.

III. Evaluation of the Information Function

Let us consider a particular occasion when the true value of the delay time τ happens to be τ_0, and write the received waveform in terms of real functions as

$$Y(t) = G(t - \tau_0) + I(t). \quad (3)$$

Here $G(t)$ is the rf waveform which would have been received in the absence of noise or of any time delay, and is assumed known *a priori*. It is also assumed that $G(t)$ is periodically modulated, and although it is convenient to use the language of pulses, the theory is, in fact, valid for any periodic modulation whatever, including frequency modulation. The function $I(t)$ represents added noise. The probability distribution for the magnitude of $I(t)$ at any particular time t is assumed Gaussian, but it is necessary here to generalize this concept. It can be shown, either by resorting to sampling-point analysis[5] or by means of a statistical mechanical argument, that the probability density for the whole waveform $I(t)$, in an appropriate number of dimensions, is proportional to

$$\exp\left[-\frac{1}{N_0}\int I(t)^2 dt\right], \quad (4)$$

where N_0 is the mean noise power per unit bandwidth.[1] The observer has access to $Y(t)$ but not to τ_0 directly, and must therefore try out all possible values of τ in turn. On the hypothesis τ, he can argue that the noise waveform alone would have to be $Y(t)-G(t-\tau)$, for which the probability density is proportional to

$$\exp\left\{-\frac{1}{N_0}\int [Y(t) - G(t - \tau)]^2 dt\right\}. \quad (5)$$

Consequently, by (2), we have

$$Q(\tau) = -\frac{1}{N_0}\int [Y(t) - G(t - \tau)]^2 dt. \quad (6)$$

The information function is thus proportional to the integrated square of the departure of the received waveform from a hypothetical noise-free waveform of lag τ. As the hypothetical τ is varied, the value which gives least-mean-square departure from the received waveform produces a maximum in the information function, and this, from the observer's point of view, is the most probable value of τ.

The limits of integration in (6) are chosen to correspond with whatever portion of the received waveform is being examined, and it is necessary to take this to be a whole number of repetition periods of the modulation. If the integrand be expanded into three terms, it will be found that the G^2 integral is independent of τ because of periodicity, and the Y^2 integral depends on τ_0 but not on τ, from (3). These two terms can consequently be omitted from $Q(\tau)$, since anything independent of τ may be absorbed into the normalization, which has already been omitted. We are left with

$$Q(\tau) = \frac{2}{N_0}\int Y(t)G(t - \tau)dt. \quad (7)$$

The integrand may be said to exist for all values of t, but τ is confined within certain fixed *a priori* limits, say between 0 and the repetition period R of $G(t)$. The domain of the integrand may be represented diagrammatically (Fig. 1) as a strip of indefinite length in the t direction, and of width R in the τ direction. If it is required to

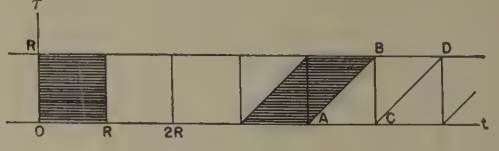

Fig. 1—Two methods of integrating range information.

form the information function $Q(\tau)$ to represent all the information contained in $Y(t)$ in the interval (O, R), then $Y(t)G(t-\tau)$ must be integrated with respect to t between the limits 0 and R for each value of τ as indicated by the shaded square. Further observation of the received waveform will entail further integrations in the obvious manner, and the limits of integration will always be represented by vertical lines on the diagram. The trouble with this process, from a practical point of view, is that all the accumulated information of any one in-

[5] C. E. Shannon, "Communication in the presence of noise," Proc. I.R.E., vol. 37, p. 10; January, 1949.

terval becomes available instantaneously at the end of the interval, and is followed by a lull while fresh integration is being performed.

Fortunately, there is an alternative method which is more natural, though mathematically less straightforward. By carrying out the integration, not in successive squares, but in parallelograms such as the one indicated on the diagram, the information function becomes available from $\tau=0$ to R (A to B in the diagram) progressively in time. The moment B has been reached, a fresh trace can be developed from C to D. In this way, we have set up a saw-tooth relationship, a time base in fact, connecting τ and t.

This process of "progressive" integration does not, of course, correspond to fixed limits on the integral (7), but to a pair of limits advancing together in time. In fact, the value of the information trace at time $t=nR+\tau$, where n specifies the nth trace and τ is confined between 0 and R is given by

$$Q_n(\tau) = \frac{2}{N_0}\int_{t-R}^{t} Y(t)G(t-\tau)dt. \tag{8}$$

It is mathematically inconvenient that the information function Q is the logarithm of an *a posteriori* probability distribution for τ only when the limits of integration are constant. In other words, each hypothesis τ should, strictly, be tested out on the same piece of the received waveform. Space does not permit a full discussion of this point, and it must suffice to remark that the progressive probability distribution

$$P_n(\tau) = e^{Q_n(\tau)}, \tag{9}$$

normalization omitted, behaves for all practical purposes as though it were a strict *a posteriori* distribution. In particular, when the information from successive periods of the received waveform is combined, either by summing the Q_n over n or by multiplying together the P_n, the resulting distribution differs from a true *a posteriori* distribution only because of end-effects, which become progressively less and less important.

IV. The Ideal Predetection Filter

The progressive information function given by (8) happens to have a very simple electronic interpretation. The form of the expression, being a linear superposition, will be recognized as that of the output from a linear filter. In fact, it is the output at time $t=nR+\tau$ from a filter whose input is the received waveform $Y(t)$, and whose impulsive response is given by

$$\delta(t) \rightarrow \begin{cases} \dfrac{2}{N_0}G(-t), & 0 < t < R \\ 0, & t < 0 \text{ and } t > R. \end{cases} \tag{10}$$

Such a filter, apart from the special scaling factor $2/N_0$, has been discussed by Van Vleck and Middleton,[6] who show that it is the unique linear filter which gives maximum peak signal-to-noise performance. (This property is, however, irrelevant to the present theory.) The filter has a frequency response which, in amplitude, has the same shape as the amplitude spectrum of one period of the input signal G, but which in phase is equal and opposite to that of G.

The output from the filter is, of course, a modulated radio-frequency waveform, and when passed through an exponential rectifying device in accordance with (9), it becomes the progressive *a posteriori* probability distribution for τ. It has already been pointed out that several traces of Q may be added together, before such rectification, if the information from several periods of the received waveform is to be combined. This is simply phase-coherent pulse-to-pulse summation, and must not be performed unless τ is completely independent of time, as has so far been assumed.

The underlying effect of this ideal filter is to cause the output signal peak to look exactly like a particularly large noise peak; all the pattern information, which originally distinguished signal from noise, has been extracted from the waveform and converted into amplitude discrimination. This may seem surprising in view of the fact that the signal and noise outputs have different power spectra. Or again, if the input signal is a square pulse, the noise output can be regarded as a multitude of overlapping square pulses, while the signal output will be a triangular pulse. However, the fact remains that a multitude of square pulses overlapping at microscopic intervals to form Gaussian noise provides a background against which the pattern of a single triangular pulse cannot be distinguished. If, indeed, pattern information could still be utilized in the filter output, one is led to a *reductio ad absurdum*, since it has been shown that the most probable value of τ is given by selecting, regardless of pattern, the largest amplitude in the filter output.

V. Discussion

The *a posteriori* probability distribution for the delay time τ has been shown to take the form of a modulated rf waveform, obtained at the output from a linear filter, distorted in amplitude or "rectified," by means of a device having an exponential characteristic. This naturally results in a function of τ whose envelope, if the signal is large enough, is peaked near the true value τ_0, but which contains under its envelope a multitude of fine peaks produced by the carrier. This fine structure represents a succession of probable and improbable values of τ resulting from comparison of the carrier phase in $Y(t)$ and $G(t)$. When this highly ambiguous knowledge of range is of no interest, it may be removed by smoothing or "detecting" the *a posteriori* distribution in such a way that areas over intervals of an rf cycle are preserved. In fact, when τ changes with time sufficiently rapidly to render the rf information out of date from one trace to the next, but not rapidly enough to affect the modulation appreciably, successive

[6] J. H. Van Vleck and D. Middleton, "A theoretical comparison of the visual, aural and meter reception of pulsed signals in the presence of noise," *Jour. Appl. Phys.*, vol. 17, p. 940; November, 1946.

traces may be combined only after removal of the rf. The detected *a posteriori* distributions must then be multiplied together, or alternatively their logarithms must be added. Mathematical readers will see immediately that, in this way, an ideal detection characteristic (of the form log I_0, where I_0 is the modified Bessel function) is uniquely specified by the theory when post-detection pulse-to-pulse summation is to be performed.

Without, for the present, developing any further the theory of removing any of the idealizations, it should be clear that any problem of extracting all the information from a noisy waveform, can, in principle, be solved uniquely and ideally by one universal method. One simply has to state the question, write down the *a posteriori* probability distribution for all possible answers to it, and interpret the resulting formula in terms of a physical device, on the principle that anything which can be computed mathematically, can also be computed electronically. No problem of waveform decoding then remains, for the *a posteriori* distribution *is* the required information; anything further is pure guesswork.

ACKNOWLEDGMENT

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Notes on an Automatic Radio-Frequency Repeater System*

JAMES A. CRAIG†

This paper is published with the approval of the IRE Professional Group on Vehicular Communications, and has been secured through the co-operation of that Group.—*The Editor.*

***Summary*—The paper describes the basic principles involved in an operating system of rf repeaters, and discusses the planning and installation of this system in Cuba. It mentions the types of antennas used and briefly describes the physical layout of the equipment involved. Also included is a resumé of the difficulties that arose and how they were overcome.**

ONE OF THE principal radio-broadcasting chains indicated about 2 years ago their need for some form of network transmission system that would enable them to overcome the inadequacies of the available Cuban telephone lines. The service provided by these lines was undependable and, when available, was noisy and wholly unsuitable from a program-quality standpoint.

The plan involved the use of radio repeaters to relay programs originating in Santiago studios near the Eastern end of Cuba and to service a network of AM broadcasting stations extending some 500 miles west to Havana. At an average 50-mile distance between repeaters this would necessitate at least ten repetitions of the program material.

To use the conventional form of repeater would have been practically impossible since demodulation and remodulation at each repeater point would have introduced a prohibitive amount of noise and distortion due to nonlinearity in the detection and modulation systems. This factor alone usually dictates a maximum of 5 or 6 repeaters even for voice-communication circuits, and the requirement in this case was for program quality. The common form of repeater, when stripped of embellishments, remains essentially a radio receiver and a radio transmitter operating back-to-back.

To overcome the foregoing limitations a radio-frequency repeater system was developed. In this repeater, as the name implies, rf is used exclusively. Frequencies between 150 and 180 mc can be accommodated by this particular system although the principles are being readily applied to the other commonly used vhf and uhf bands. The actual frequency range used in the Cuban system is from 163 to 170.2 mc.

From the functional block diagram in Fig. 1 it is seen that a typical operating frequency of 165.0 mc has been chosen as the incoming carrier for the purpose of illustration. This frequency is fed from an antenna to a single stage rf amplifier. From this amplifier it is heterodyned with a locally generated signal originating in a "channel" oscillator. This oscillator is controlled by a quartz crystal operating as a harmonic oscillator at a frequency of approximately 45 mc. The crystal frequency is tripled and then amplified at 137.5 mc, as chosen in the block diagram, and is then fed to the first mixer stage. This crystal is the only one that requires changing when a different carrier frequency is to be used. The beat frequency between the incoming signal and the local oscillator is always 27.5 mc for any incoming carrier, and this frequency enters the first intermediate frequency amplifier consisting of two high-gain stages.

As the signal leaves the first IF amplifier, the user can elect to retransmit on a frequency which is either

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4.8 mc below or 5.2 mc above the incoming signal frequency. It will be noted that the signal can enter either one of two paths, each consisting of a second mixer and a second IF amplifier. These parallel circuits are so arranged that a selector switch energizes the cathode heaters of one branch or the other. High B+ voltage is continuously available to both branches, but only the one selected will draw B+ current.

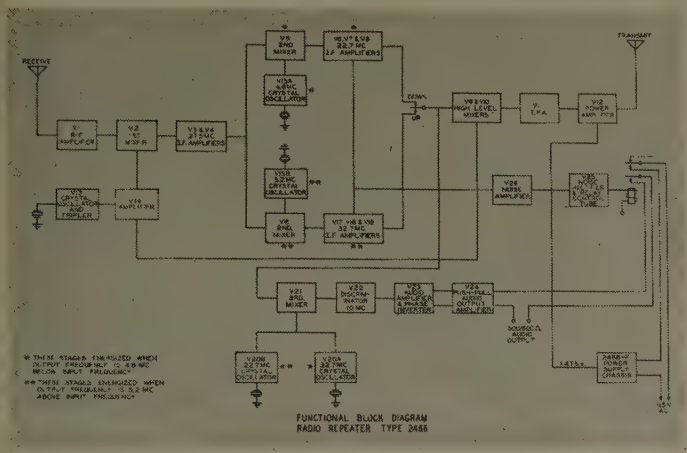

Fig. 1—Radio repeater, functional block diagram.

Assuming that retransmission is to occur on a frequency which is 4.8 mc below that of the incoming signal, the selector switch would be thrown to the "Down" (down in frequency) position. The upper branch on the block diagram would then be energized and the 27.5-mc signal would beat in the second mixer against a 4.8-mc signal locally generated by a crystal oscillator. This produces a 22.7-mc signal which is then amplified by the second intermediate amplifier. This intermediate amplifier consists of four stages. The first two stages function as straight amplifiers and the third and fourth stages act as cascaded limiters. Any incidental amplitude modulation of the IF signal is reduced in the third stage and fully removed in the fourth stage.

This purely frequency-modulated signal next enters a balanced high-level mixer where it again combines with the same 137.5-mc signal derived from the channel oscillator. This results in a 160.2-mc signal which is used to excite an intermediate-power amplifier stage which then, in turn, excites the final power amplifier having an output power of 50-watts nominal. The signal then passes to the outgoing antenna for transmission to the next repeater point at a frequency 4.8 mc below that of the incoming signal frequency, which was 165 mc.

Had the alternate second mixer and IF path been selected, by throwing the selector switch to the "UP" position, it can be seen that a local 5.2-mc signal would have converted the 27.5-mc signal from the first IF amplifier to a frequency of 32.7 mc. The signal would beat with the 137.5-mc channel oscillator frequency in the balanced high-level mixer to produce a final output frequency of 170.2 mc.

The purpose of shifting the transmission signal up or down by unequal amounts is to prevent interference between the different repeater stations in the system. Since the carrier frequency is raised by 5.2 mc and lowered by 4.8 mc at successive repeater points, no two repeater stations in such a chain will transmit at the same frequency.

As can also be noticed in the block diagram, an audio takeoff is provided for modulation of a member AM broadcast station of the chain or for monitoring purposes. This is accomplished by diverting a small portion of the 22.7- or 32.7-mc energy leaving the second IF amplifier, and combining it in a third mixer stage with a locally generated 32.7- or 22.7-mc signal, respectively. A second selector switch selects which of these crystal

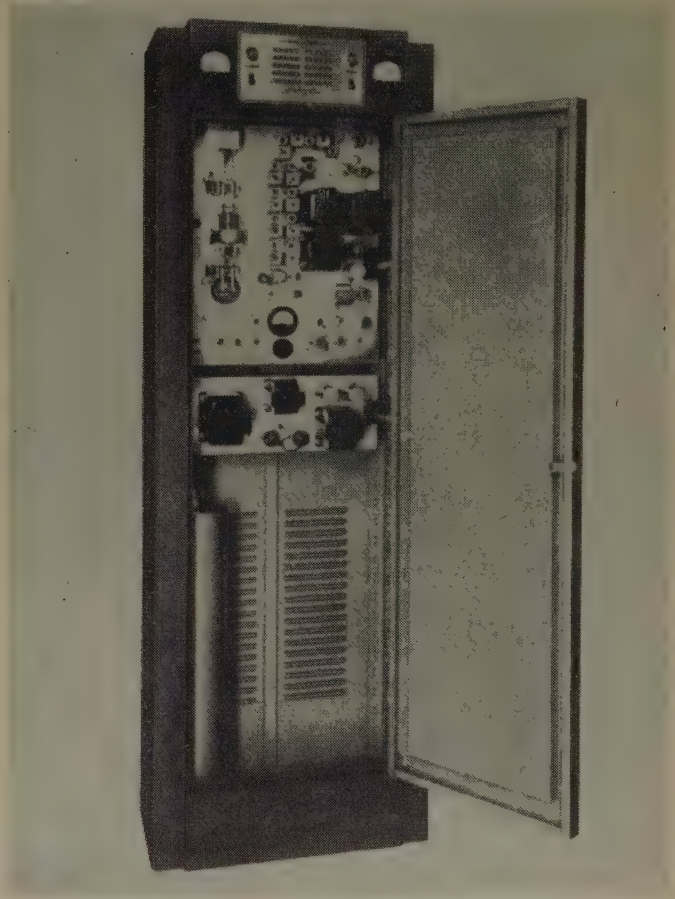

Fig. 2—Radio-repeater equipment, front view (Type 2486).

controlled oscillators is used, which depends, in turn, on the position of the first selector switch. In this manner, the output of the third mixer stage always produces a 10-mc signal which is fed to a balanced discriminator. The audio leaving the discriminator is then passed through a de-emphasis circuit and applied successively to an amplifier, a phase inverter, and a push-pull audio amplifier, which delivers audio at zero level across a termination impedance of 500 or 600 ohms.

The repeater is automatically turned on or off by a relay tube, which functions by virtue of noise present

at the screen grid of the limiter tube in the second IF amplifier when an rf carrier signal is absent. The time constant of the limiter grid circuit is designed to be long compared to its IF frequency but sufficiently short to follow the rapidly fluctuating noise peaks. In the absence of a carrier this noise is amplified and then rectified and applied as negative bias to the grid of a tube having a relay winding as its plate load, thus causing the relay to be unoperated. In this condition the relay cuts off the high-voltage supply to the power-amplifier stage and opens the local audio output circuit. As soon as a carrier is received, the noise is reduced by the limiter, the relay operates, the repeater goes on the air and the local audio output circuit is closed. The bias on the noise rectifier diode can be adjusted to cause relay operation by an rf carrier of any level between 3 and 15 μv.

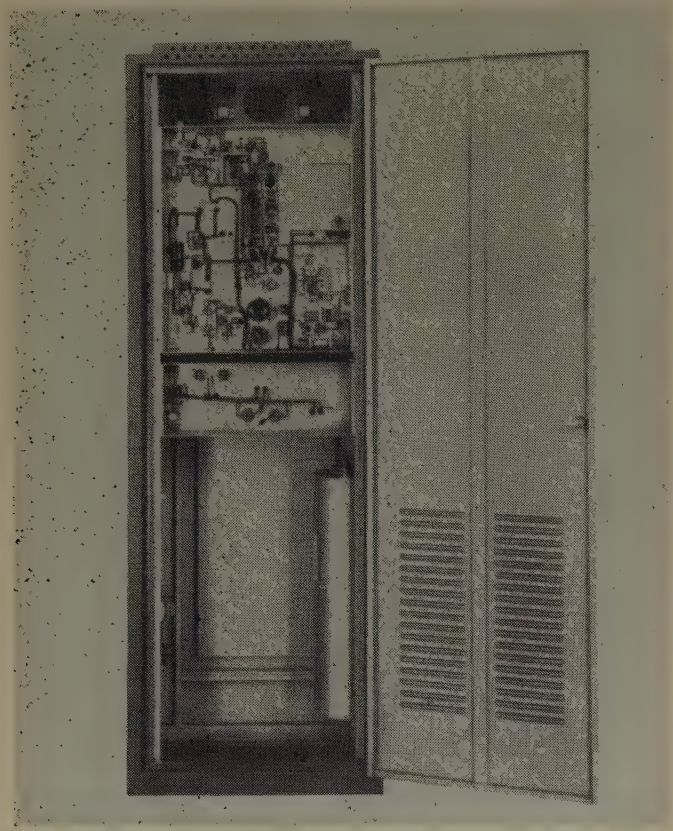

Fig. 3—Radio-repeater equipment, rear view (Type 2486).

Fig. 2 shows the front view of the repeater. The entire repeater is contained on the upper chassis, with the exception of its power supply which is contained on the lower small chassis. All necessary meters and switches for normal control of the equipment are accessible outside of the cabinet.

Fig. 3 shows the rear view of the same equipment. This cabinet is 72 inches high, providing sufficient room for the addition of a cavity resonator which is included to insure noninterference from signals outside of as well as within the system. These figures illustrate the accessibility of all parts of the equipment to provide easy servicing and maintenance.

In addition to the design of the equipment itself, other problems affected its utilization in the Cuban system. The map of the island of Cuba shows Santiago as the point of origin and Havana as the terminal (Fig. 4). It was imperative that, if at all possible, the repeater jumps should be so located that repeaters would occur at points where there were broadcast stations so that audio modulation could be immediately available to that station. A more economically important reason is that the AM radiators could be utilized as repeater towers for the repeater antennas. These AM station locations are at Guantanamo, Holguin, Tunas, Camaguey, Ciego de Avila, Santa Clara, Cienfuegoes, Colon, Matanzas, and Havana.

A complete study of the topography was made and profile curves prepared for each tentative jump. A minimum signal of 5 microvolts was decided upon as being necessary to insure proper operation of the system. Standard nomographs were employed to estimate propagation over each of the paths. These took into account the basic distance involved and the effect, if any, of intervening hills. These results were then adjusted to accommodate known factors involving antenna height, antenna gain, rf power being used, possible

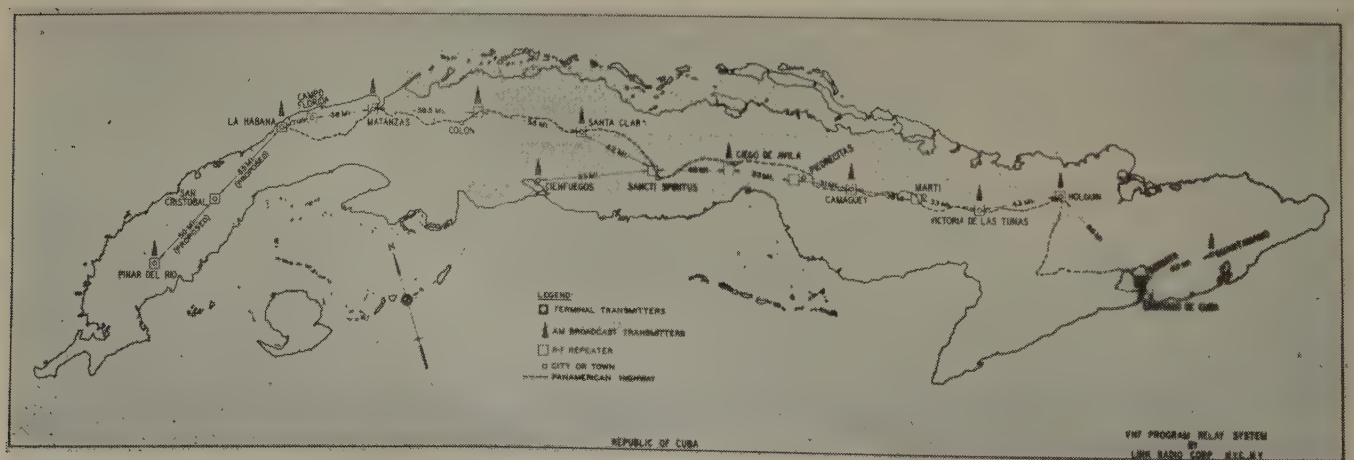

Fig. 4—Map of Cuban repeater installation.

6-db fades, and transmission-line losses. In the majority of cases these predictions worked out remarkably well in practice. However, tests showed that in two of the jumps, where the terrain was comparatively smooth, only insufficient signal was available. (These two jumps were from Tunas to Camaguey and from Camaguey to Ciego. As shown by the map, these two jumps were broken up into four jumps, with added repeaters at Marti and Piedrecitas.) The signal arriving at Marti from Tunas averages 21 μv with practically no recorded fades. The signal at Piedrecitas runs about 15 μv with 6-db fades occurring mostly at night.

A 250-watt terminal transmitter is located at Mt. Boniato about 4 miles north of Santiago, and the antenna was originally directed at Holguin. This terrain is quite rough, indicating the need for 250 watts of power on this jump. However, it was found that 50 watts would give ample signal into Holguin. This error, if it can be so called, was used to good advantage, however, because now the 250 watts of power at Boniato are being split into two antennas and directed to Holguin as originally planned and also to Guantanamo to the east, with approximately 100 watts used in each direction.

All antennas used in the repeater system are high-gain, broadband Yagi arrays, such as that shown in Fig. 5. The design of these antennas was originally prompted by the requirements of this repeater system although they are now being used successfully in many other installations. Actually, four types of Yagi arrays,

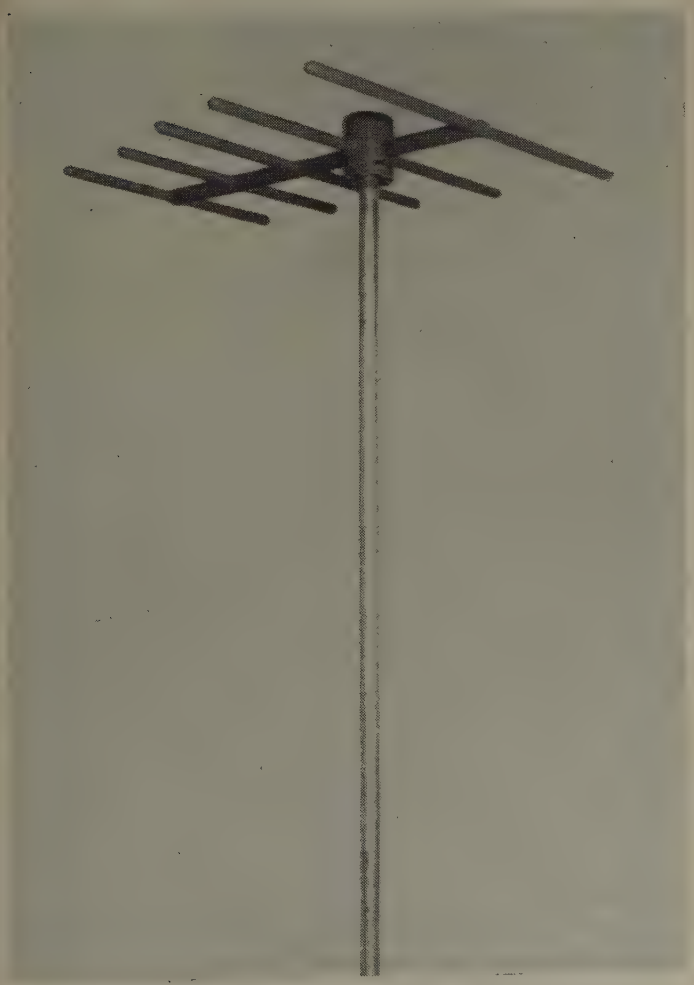

Fig. 5—Yagi antenna array used at terminal and repeater stations (Type 2488 A and B and 2489 A and B).

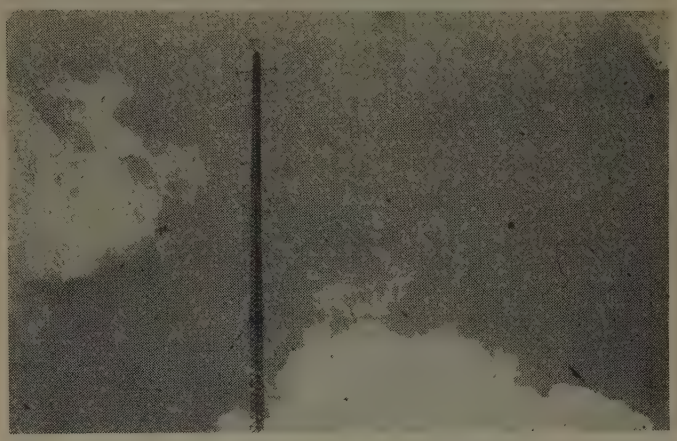

Fig. 6—Yagi antennas mounted at the top of the Camaguey AM radiator.

Fig. 7—Yagi antennas at top of tower. Mount Boniato terminal transmitter.

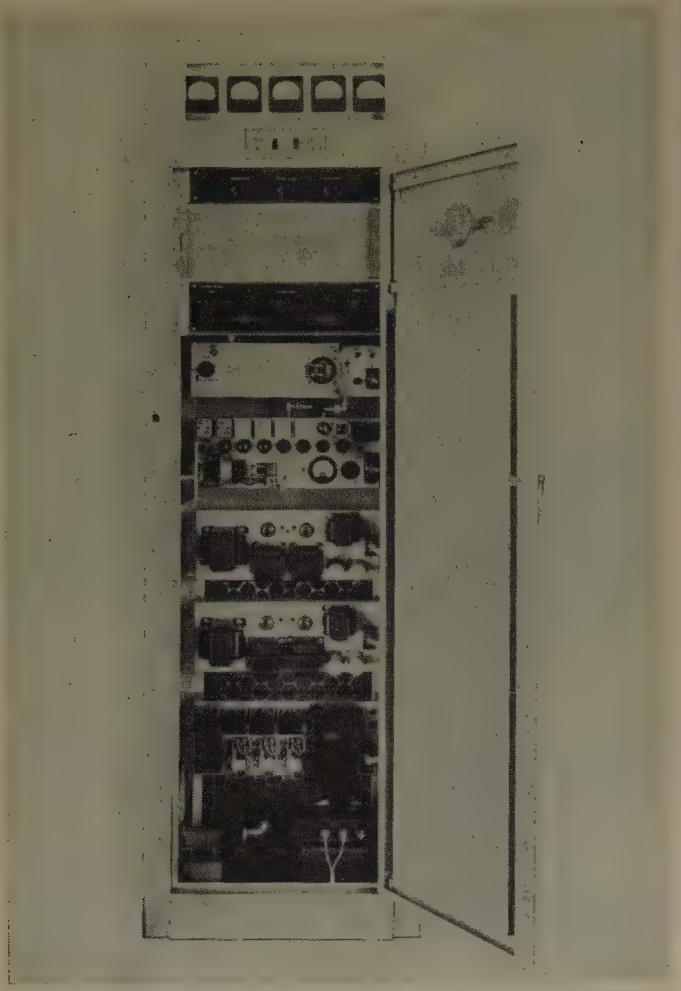

Fig. 8—Terminal-transmitter equipment, front view (Type 2485).

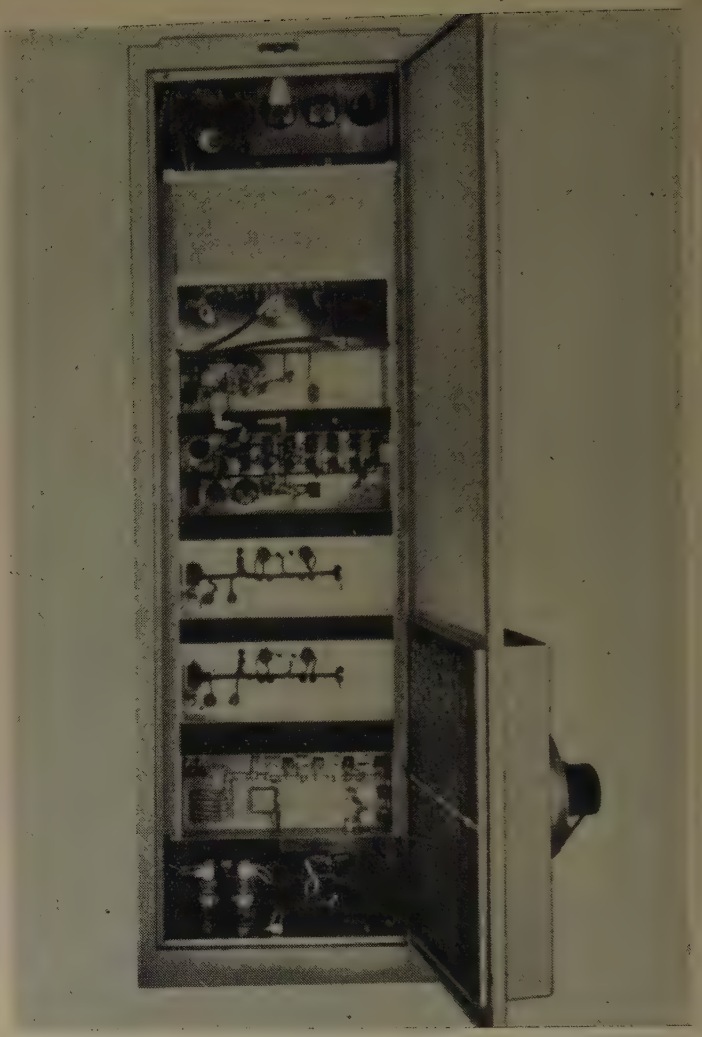

Fig. 9—Terminal-transmitter equipment, rear view (Type 2485).

each having a bandwidth of 5 mc are available for use between 152 and 172 mc. The characteristics of each type are almost identical, each having a front-to-back ratio of 22 db and a forward gain of 9 to 10 db over a half-wave dipole. The beam width of the half-power points is about 35 degrees. Each antenna has a nominal impedance of 50 ohms and each has a "bazooka" converter to adapt the balanced antenna to the unbalanced transmission line. Mechanically, the arrays are constructed of brass and are sufficiently strong to amply withstand wind velocities in excess of 100 miles per hour with severe ice-loading. Mounting facilities permit the use of the arrays with either horizontal or vertical polarization.

Figs. 6 and 7 show some of the typical tower installations. In each case, the Yagi arrays include those used for transmitting and for receiving. The tower shown in Fig. 6 is the Camaguey AM broadcast radiator, such as those used where available. In other cases, towers were erected at repeater sites where no AM broadcast stations existed. Fig. 7 shows one of these towers at the terminal transmitter location on Mt. Boniato. Another consideration in the location of the repeater sites was the availability of primary ac power. This power in Cuba leaves something to be desired in both voltage and frequency regulation. However, each repeater is equipped with a voltage regulator to accommodate wide voltage fluctuations and also with an automatic emergency power supply.

At the terminal transmitter on Mt. Boniato there is a wide-band FM receiver which is energized 24 hours a day. This receiver includes a carrier-operated relay which operates upon receipt of a signal from a 15-watt FM transmitter located on top of the Santiago studio building. When the carrier-operated relay operates, it automatically places the terminal transmitter on the air through suitable time-delay relays. As the transmitter comes on the air, it then energizes the Holguin repeater, which energizes the next repeater and so on to the other end of the system, automatically placing the entire repeater chain on the air.

It is interesting to note that the Santiago AM transmitter now receives its modulation from a receiver which picks up the signal from the terminal transmitter on Mt. Boniato. Since the distance involved is so short, sufficient radiation is received from the back-lobe of the Yagi arrays at the terminal transmitter to produce a usable signal at the AM transmitter site. Originally, the terminal transmitter was controled by an AM receiver located on Mt. Boniato and tuned to the Santiago AM

transmitter. The AM transmitter was at that time connected to the studios by a leased line. However, since changing over to the present arrangement, even the the studio-to-transmitter leased line in Santiago has been dispensed with, which not only eliminated the line charges, but also definitely improved the quality of the audio arriving at the AM transmitter.

Fig. 8 shows a front view of the terminal transmitter. The power-amplifier power supply is located on the cabinet floor. Situated on the first chassis are the control, time-delay, and overload protective circuits. The next two chassis are the exciter and intermediate-amplifier power supplies, respectively. Then follows the exciter chassis, intermediate power-amplifier chassis, and finally the power-amplifier stage. Fig. 9 shows the rear view of the same cabinet, and emphasizes the complete accessibility of all parts for servicing. Note that the rear door includes a blower and Dustop filters. This blower automatically cuts in at ambient temperatures above 85 degrees F., and pressure ventilates the entire cabinet.

Each piece of equipment in the system has been designed so that it would operate over long periods of time without the need for frequent service and so that it would make servicing, when required, as simple and easy as possible.

After the system was originally installed, some trouble was found to originate with the antennas which accounted for about 5 per cent of the system outages. It was found that in the torrential tropical downpours, water would find its way into the antennas and cause detuning. Since then, however, the antennas have been modified and waterproofed differently, with the result that interruptions from this cause have disappeared.

Furthermore, each repeater is now equipped with an emergency power source which automatically cuts in upon the loss of primary power. Initially, more than 90 per cent of the outages in the system were from loss of primary power, and called for an emergency source that would instantaneously take over. This has been provided in the form of a 28-volt storage-battery bank which is maintained by a trickle charger. In the event of a power failure, a rotary converter, generating 110 volts at 400 cycles, supplies the equipment with power. 400-cycles were chosen to effect a reduction in converter size, and this imposed no limitations as far as the repeater equipment was concerned since it was designed to operate on any power frequency from 50 to 400 cycles.

Since making these two changes, the outages have been reduced to a negligible amount and the system has been performing very nicely. In fact, its performance has been so satisfactory and so vastly superior to that previously afforded by telephone lines that the system is to be extended west of Havana to Pinar del Rio. Furthermore, Cadena Oriental de Radio is currently building new studios in Havana, which, when completed, will create the need for a similar system operating eastward from Havana to Santiago and Guantanamo; these will be installed in the near future. This fact alone is probably one of the best indications of the suitability of this system of rf repetition for multi-hop repeater systems.

Direction Finder and Flow Meter for Centimeter Waves*

KIYOSHI MORITA†

Summary—**A new direction finder for cm waves has been developed which indicates the wave direction by the minimum response of a dipole placed at the focus of a small paraboloidal reflector. It works well irrespective of whether the polarization of the waves is horizontal or vertical.**

A new flow meter has also been developed which indicates directly the active power flow of the waves, in magnitude and direction. It will serve most effectively in the study of wave diffraction. With an ordinary mirror galvanometer the author has succeeded in measuring the energy flow of 1 μw per cm^2 at the wavelength of 10 cm.

I. Introduction

THE INCREASING NEEDS of microwave communication necessitates an accurate and complete study of wave nature. Although much work has been done on plane waves of definite polarization, not much has been contributed on the study of waves diffracted by some obstacles. In this case the polarization may be altered and the direction of the waves changed; the energy flow is not necessarily determined by the squared value of electric-field intensity.

Consequently, it may not be meaningless to develop a new direction finder which can tell wave direction accurately whether the plane of polarization is vertical or horizontal, and to develop an energy flow meter.

It is well known that when plane waves are reflected back by a metallic sheet placed at right angles to the direction of wave propagation there will be standing waves developed showing that some of the energy is reflected by the sheet. To know the amount of net energy absorbed in the sheet we have to measure the crest and bottom values of the electric-field intensity of the standing waves. This paper deals with the development of a new indicator which can show directly the net energy flow based on a single point measurement.

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II. Direction Finder

A. *Principle of Direction Finding*

Fig. 1 shows a paraboloidal reflector having a dipole antenna placed at the focus and in a direction coincident with the axis. The antenna is connected to a receiver amplifier by a coaxial transmission line. When plane waves come along the axis of Z, toward the paraboloid, the receiver will show no indication. But when the paraboloid is slightly changed in its bearing, the antenna

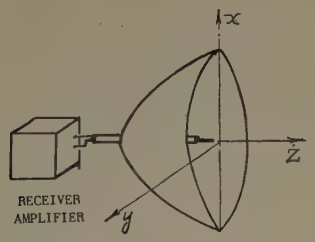


Fig. 1—Paraboloidal reflector and dipole.

will pick up part of the wave energy. The amount depends on the direction of electric vector in the coming waves and on the direction of steering. If the waves are vertically polarized, steering the paraboloid in a horizontal plane does not give rise to any indication in the receiver, whereas steering in a vertical plane does. Thus, we fail to determine the direction of coming waves in the horizontal plane when the waves are vertically polarized. Likewise, we will fail to determine the direction in the vertical plane when the waves are horizontally polarized.

In Fig. 2 a novel means to get rid of those defects is shown. It consists of a pair of quadrant shades made of metal sheet and placed at the face of the paraboloid. When the vertically polarized waves approach along

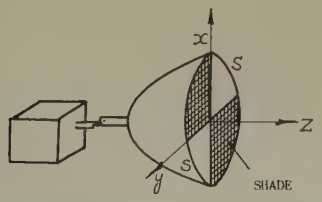


Fig. 2—Paraboloid with quadrant shades.

the Z axis, toward the paraboloid, a part of the energy is reflected back by the pair of quadrants and the rest enters into the paraboloid. The latter can be considered as consisting of two partial waves, one with its electric vector perpendicular to the arc of rim S and the other with its electric vector parallel to S. Of these two, the former partial waves only contribute to direction finding. They give an indication on the receiver when the paraboloid is steered.

Figs. 3(a) and 3(b) illustrate these circumstances. With an ordinary paraboloid the general tendency of the output of receiver versus steering angle is shown in

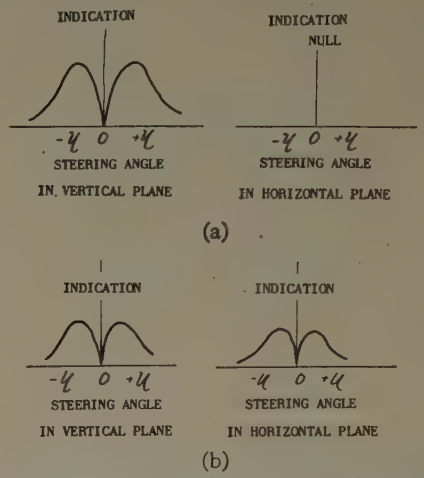


Fig. 3—Waves polarized in a vertical plane. (a) Characteristics of an ordinary paraboloid. (b) Characteristics of a quadrant paraboloid.

Fig. 3(a), while with the new quadrant paraboloid the characteristics are given in Fig. 3(b). Thus, in the latter case only we have a device which gives the direction of wave propagation in terms of the angles in vertical and horizontal planes.

B. *Calculation of Directional Property*

In calculating the directional property of the paraboloid with a dipole placed along the axis at its focus let us take an analytical figure of the paraboloid, as in Fig. 4. The focal point is indicated by F and the downcoming waves by SP. This contributes to the output of the dipole at F only if the electric vector of the waves has a component in the plane OPF. The contribution is calculated on the basis that it is inversely proportional to the distance r between F and P.

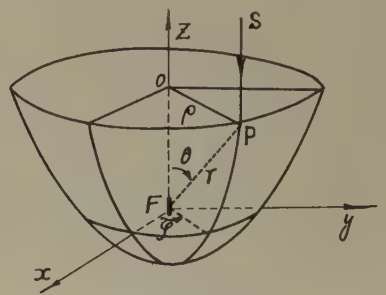


Fig. 4—Paraboloid.

Generally, the wave front is not necessarily perpendicular to the Z axis, and the waves which arrive at the opening of the paraboloid differ in their phases point by point; this must be taken into account in the calculation of the directional characteristics.

The calculated values are as follows:

$$\frac{E_p}{E_0} = j\left(\frac{2\pi f}{\lambda}\right)\cdot f_p\cdot\cos\eta;$$

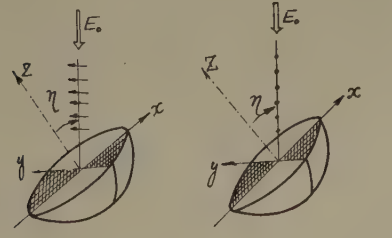
$$f_p = \frac{1}{2}\int_0^{t_0}\left[\frac{4t}{4+t^2}\right]^2\cdot J_1(k)dt \qquad (1$$

$$\frac{E_v}{E_0} = j\left(\frac{2\pi f}{\lambda}\right)\cdot f_v\cdot\cos\eta;$$

$$f_v = \frac{1}{\pi}\int_0^{t_0}\left(\frac{4t}{4+t^2}\right)^2\left[\frac{1-\cos k}{k}\right]\cdot dt,$$

where

E_0 = electric-field intensity incident on the paraboloid
E_p = induced electric-field intensity at the focus when the polarization is parallel with the incident plane (Fig. 5(a)).
E_v = induced electric-field intensity at the focus when the polarization is vertical to the incident plane (Fig. 5(b)).
f = focal distance
λ = wavelength
η = incident angle
$t_0 = a/f$
a = radius at the opening of the paraboloid
$t = \rho/f$
ρ = radius of the paraboloid at the arbitrary section
$k = (2\pi f/\lambda)t\cdot\sin\eta$



(a) (b)

Fig. 5—Waves incident in the XZ plane.

$J_1(k)$ = Bessel function of the first order of modulus k. The integrals involved in E_p, and E_v are not easy to handle in more concrete form, and it is necessary to have their characteristics after numerical calculations.

The author calculated the directional characteristics for the case when

$$a = \rho_0 = 7.5 \text{ cm}$$
$$\lambda = 10 \text{ cm}$$
$$f = 2 \text{ cm}.$$

The results are shown in Fig. 6.

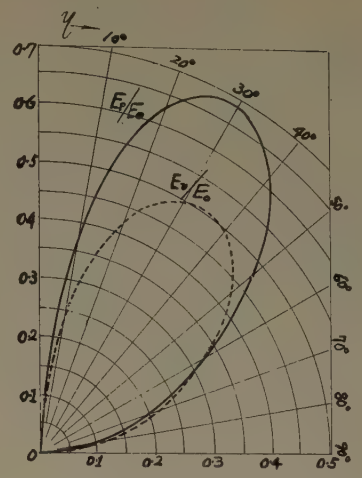


Fig. 6—E_p/E_0 and E_v/E_0 versus η for quadrant paraboloid of dimensions. $\rho_0 = 7.5$ cm and $f = 2$ cm working at $\lambda = 10$ cm.

C. *Experimental Result*

Experiments were carried on with a paraboloid shown in Fig. 7. It is shaped like a trophy cup and differs greatly from the ordinary paraboloid in that its focus is very deep near the bottom. Calculation shows that the trophy cup will give a much more sharp directivity than an ordinary paraboloid for a given diameter of the opening. In the experiment a 10-cm wavelength was used, and at the output terminals of the antenna a crystal detector is connected directly, which in turn gives a deflection on a galvanometer. The experimental results obtained on directional characteristics for horizontally polarized waves are given in Figs. 8(a) and 8(b).

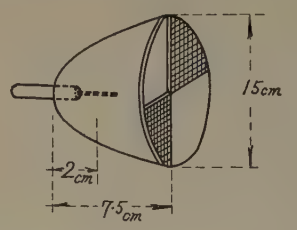
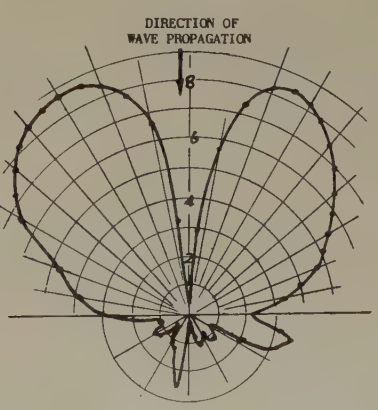
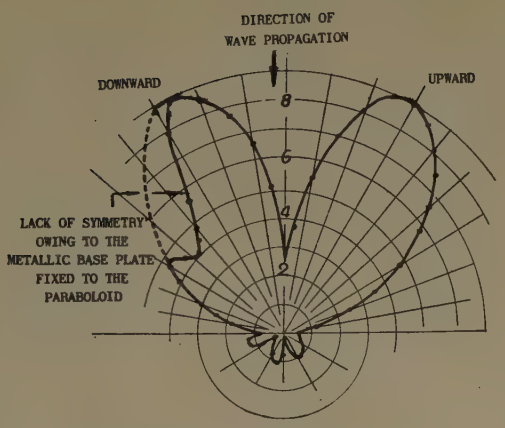


Fig. 7—Experimental paraboloidal reflector.



(a)

Fig. 8(a)—Directional characteristics in a horizontal plane



(b)

Fig. 8(b)—Directional characteristics in a vertical plane.

Fig. 9 shows a series of contour lines with output figures as parameters when the bearing of the paraboloid is changed. In the figure the co-ordinates give the bearing in degrees when the electromagnetic field is horizontally polarized.

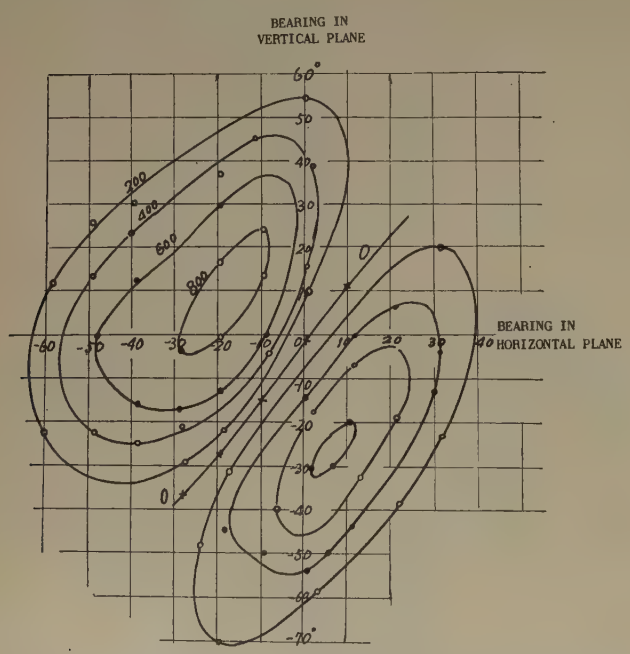


Fig. 9—Contour lines for a constant output. Figures denoted on each curve show the relative magnitude of output intensity.

We see that, instead of a single zero point, there is a line of zero intensity coinciding with the center line of the shading quadrant. Therefore, it is necessary to get another zero line crossing the above one to determine the true direction of the waves. This may be obtained by rotating the 90° quadrant around its periphery and again measuring the line of zero intensity. Thus, we can obtain two lines of zero intensity crossing each other, the cross point giving the direction of the waves under question, as shown in Fig. 10.

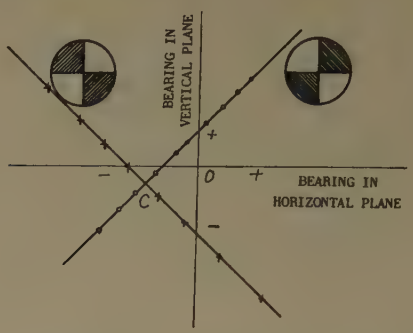


Fig. 10—Determination of direction of propagation by intersection of two lines of zero intensity.

D. *Note for Practical Application*

We know that waves are not necessarily polarized in a simple vertical or horizontal direction. To measure the direction of the wave for arbitrary polarization we have such an arrangement that the shading quadrant can be rotated around the periphery of the paraboloid and be set up at a suitable position. Thus in the case of waves polarized at 45° with the horizontal we have to turn the quadrant 45° more or less, as shown in Fig. 6, and examine the patterns.

In the above description the shading quadrant is made of plain metal sheet. It was found later that better results could be obtained in the directional pattern when a wet cardboard of a few millimeters thickness is placed on the outside surface of this metal shade. It absorbs rather than reflects the wave energy impinging on the shade, and consequently the pattern becomes simpler in shape, showing no subsidiary lobes nor back response.

III. Flow Meter

A. *Conception of Energy Flow*

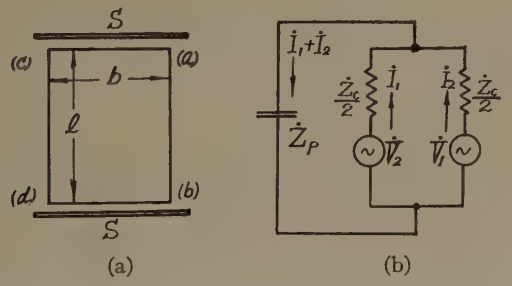
The energy flow of an electromagnetic field can be indicated by the real part of Poynting vector, that is $(E \cdot H^*)$, where E is the electric and H^* the conjugate of the magnetic field vector. In the case of plane waves H is intimately connected to the electric field, and it may be said that $(E \cdot E^*)$ will give a measure of energy flow. This is the reason why we usually estimate the energy flow by a simple dipole. However, when there is any reflected wave, we will have standing waves in space and the output of a dipole will vary in wide range depending on its position. In such case a dipole never tells about energy flow; it is fundamentally a sort of field-intensity meter.

The author has devised a new flow meter which will give the magnitude of net energy flow, even when there

are standing waves. By this apparatus, measurement at one point in space will give sufficient information about the density of energy flow and its direction at that point.

B. *Principles of the Apparatus*

Fig. 11(a) shows the principle of measurement. Here *abcd* indicate a small loop made of a copper wire and *ss* small metal plates placed perpendicular to the plane of the loop and capacitively coupled to the end straps *ac* and *bd*. Now assume a plane wave coming, with its electric vector, in the direction *ab* or *cd*. Then the current induced in the sides of the loop can be calculated with ease when we consider an equivalent circuit of the loop, as shown in Fig. 11(b). It has two generators supplying voltages of equal magnitude but of unequal phase in general. Z_c means the impedance of the loop for circulating current owing to the difference of these two voltages. Especially when the wave comes in a normal direction to the plane of the loop, no circulating current exists; but there still remains another current flowing in parallel through the sides of the loop, and its magnitude will be determined by the total impedance $\overline{Z}_p' = \overline{Z}_p + \overline{Z}_c/4$.



(a) (b)

Fig. 11—Flow meter. (a) Simplified sketch. (b) Equivalent circuit.

When the dimensions of the loop are small in relation to the wavelength, Z_p' can be made high capacitive impedance. Now allowing $\overline{V}_1\overline{V}_2$ to be the induced voltage in each side of the loop and $\overline{I}_1\overline{I}_2$ the current through it, we have the following equation:

$$\begin{aligned} \overline{I}_1(\overline{Z}_c/2) + (\overline{I}_1 + \overline{I}_2)\overline{Z}_p &= \overline{V}_1 \\ \overline{I}_2(\overline{Z}_c/2) + (\overline{I}_1 + \overline{I}_2)\overline{Z}_p &= \overline{V}_2 \end{aligned} \tag{2}$$

and

$$\begin{aligned} \overline{I}_{1.2} &= \frac{1}{2\overline{Z}_p'}\left(\frac{\overline{V}_1+\overline{V}_2}{2}\right) \pm \left(\frac{\overline{V}_1-\overline{V}_2}{\overline{Z}_c}\right) \\ \overline{Z}_p' &= \overline{Z}_p + \frac{\overline{Z}_c}{4}. \end{aligned} \tag{3}$$

Now we want to choose the value of the impedances in such a way that I_2 becomes zero when the plane wave impinges upon the loop from right to left. Let $\overline{E}_0$ be the electric-field intensity at the center of the loop and l and b the length and span, respectively, of the loop. We then have

$$\begin{aligned} \overline{V}_{1.2} &= \overline{V}_0 e^{\pm j\theta/2}; \qquad \overline{V}_0 = l\overline{E}_0 \\ \theta &= 2\pi b/\lambda; \qquad \lambda = \text{wavelength}. \end{aligned} \tag{4}$$

Substituting these into (3) we obtain

$$\overline{I}_{1.2} = 2\overline{V}_0\left(\frac{\cos\theta/2}{4\overline{Z}_p'} \pm j\frac{\sin\theta/2}{\overline{Z}_c}\right). \tag{5}$$

The condition that $\overline{I}_2$ be zero will lead to

$$\overline{Z}_c = j4\overline{Z}_p \tan(\pi b/\lambda). \tag{6}$$

This forms the basic requirement of the flow meter, and under this condition we have

$$\begin{aligned} \overline{I}_1 &= j(4\overline{V}_0/\overline{Z}_c)\sin(\pi b/\lambda) \\ \overline{I}_2 &= 0. \end{aligned} \tag{7}$$

If we use thermojunction to measure current, the output G will be proportional to the squared value of the current. Thus we have

$$G_1 = 16\,k\,V_0^2\frac{1}{|\overline{Z}_0|^2}\sin^2\left(\frac{\pi b}{\lambda}\right) \tag{8}$$

$G_2 = 0$

$G = G_1 - G_2$

k = a certain coefficient of the galvanometer

G = the energy flow of the plane wave.

We shall show further that if there be any reflected wave the difference of the junction output G_1-G_2 gives the net energy flow. Assume the plane wave comes from right to left, that is, in the $-Z$ direction, and a part of its energy is reflected back the opposite way; the electric field then becomes

$$\overline{E} = E_i e^{j(2\pi/\lambda)z} - E_r e^{-j(2\pi/\lambda)z}, \tag{9}$$

where E_i means incident wave and E_r reflected wave. The induced voltage on each side of the loop becomes

$$\begin{aligned} \overline{V}_1 &= V_i e^{j(2\pi/\lambda)(z+b/2)} - V_r e^{-j(2\pi/\lambda)(z+b/2)} \\ \overline{V}_2 &= V_i e^{j(2\pi/\lambda)(z-b/2)} - V_r e^{-j(2\pi/\lambda)(z-b/2)} \end{aligned} \tag{10}$$

and the substitution of this equation into (3) and (6) will give

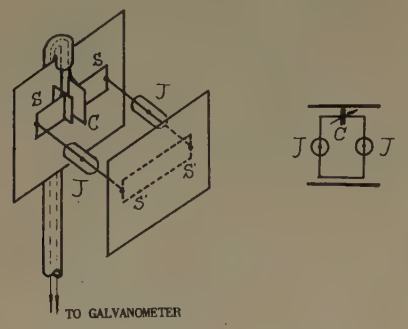
$$\overline{I}_1 = j4\frac{V_i}{\overline{Z}_c}e^{j(2\pi/\lambda)z}\sin\frac{\pi b}{\lambda} \tag{11}$$

$$\overline{I}_2 = j4\frac{V_r}{\overline{Z}_c}e^{-j(2\pi/\lambda)z}\sin\frac{\pi b}{\lambda}. \tag{12}$$

Therefore, $\overline{I}_1$ again indicates the incident wave and $\overline{I}_2$ the reflected wave, and the difference of the output of the thermojunctions will give $V_i^2 - V_r^2$, which means the net energy flow.

C. *Construction of the Apparatus*

It is necessary to make the flow meter dimensions small in proportion to the wavelength under measurement. The author suggests two types of flow meter, as shown below: one for the decimeter wave region and

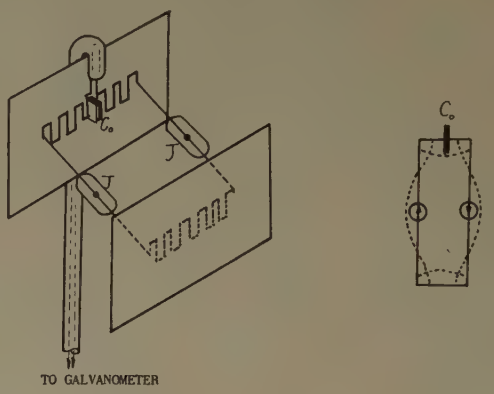


(a) (b)

Fig. 12—Flow meter for decimeter waves.

another for the centimeter region. Figs. 12(a) and 12(b) represent a flow meter for decimeter waves and its circuit diagram. In Figs. 12(a) and 12(b) J is a thermoconverter sealed in an evacuated glass bulb and serves as a generator of thermo emf as well as electric heater; C is a variable capacitor for getting near resonance in a loop circuit; and ss are pieces of insulated copper plates forming a capacitor in free space. At the same time ss are coupled capacitively to the end of the loop, where they are to be likened, in ordinary sense, to some loading capacitor to an antenna. The size of ss, the gap between ss and the end straps, and the resistance of the junction wire should be so chosen that (6) will be satisfied. Whether the impedances are properly chosen or not can be checked by exposing the apparatus to a field of plane waves where the voltage-standing-wave ratio is already known and by observing the output from each junction separately. If the indication does not change when the apparatus is displaced a little, say $\frac{1}{4}$ wavelength along the line of propagation, the condition may be considered satisfied.

Furthermore, it is necessary to have such an arrangement that, in favor of the screening action of ss, emf will not be induced in the end straps of the loop even if the loop is tilted. This will benefit good directivity characteristics of the flow meter.



(a) (b)

Fig. 13—Flow meter for centimeter waves.

Fig. 13(a) is a flow meter for a centimeter-wave region. As the wavelength is too short, it is advisable to utilize harmonic excitation of the loop, as shown in Fig. 13(b) and to fold it up at the terminals so that small dimensions as a whole may be obtained. C_0 is a blocking condenser to avoid short-circuiting the thermo emf.

D. *Sensitivity*

We constructed a flow meter for a 15-cm wavelength with a thermojunction having 40 ohms resistance and generating 6 mv at the current of 10 ma, and a loop having dimensions 3×2.2 cm (i.e., $b=2.2$ cm). It can detect 1 μw per square cm per 10-mm deflection when a galvanometer of 8.3×10^{-8}amp/cm sensitivity is used as detector.

We utilized this flow meter to study some diffraction phenomena, in the case where the plane waves are distorted by a metallic sphere having a diameter 1.2 times that of the wavelength used, and fairly good results coinciding with calculations were obtained.

CORRECTION

W. W. von Wittern, co-author with H. E. von Gierke of the paper, "Condenser Microphone Sensitivity Measurement by Reactance Tube Null Method," which appeared on pages 633–635 of the June, 1951 issue of the PROCEEDINGS OF THE I.R.E., has requested that the editors publish the following correction:

The caption of Fig. 3 should read: Sensitivity and phase lag of two different microphones. Radial scale = sensitivity in db ref. 1 volt/dyne/cm^2. Angle of the radii = phase lag in degrees between pressure acting on the membrane and output voltage. Numbers along the curves = frequencies in cps.

Modified Locked-Oscillator Frequency Dividers*

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Summary—**A simple locked-oscillator frequency divider is described. The circuit, which consists of an *LC* oscillator modified to facilitate locking, is capable of operating over a 7-to-1 plate-supply-voltage range when dividing by a factor of 30.**

Introduction

FREQUENCY DIVIDERS have seen wide application where precise time intervals or accurate audio frequencies are required. This results from the fact that it is possible, with present techniques, to obtain the highest oscillator frequency stability at frequencies of the order of 50 or 100 kc. Lower frequencies may be required for running clocks, for interpolation, or for many other purposes, and therefore frequency division is required.

Although several types of frequency dividers have been employed,[1–7] a need was found for a simple but reliable circuit capable of dividing by steps of 10 or greater in a single stage.

Improved Locked Oscillator

In developing the frequency divider to be described, an attempt was made to combine the frequency stability of the locked sinusoidal oscillator with locking ability of the multivibrator.

An analysis has shown[7] that if a voltage of frequency Nf_0 is injected into an oscillator of frequency f_0, synchronization may occur because of cross modulation between the injected voltage and harmonics of f_0. The modulation product can be considered as a synchronizing signal for locking with a one-to-one frequency ratio. It is well known that one-to-one locking is comparatively easy in any nonlinear oscillator.[8,9] Thus it might appear that the synchronizing ability of a sinusoidal oscillator as a frequency divider might be improved by increasing its harmonic content.

A regenerative sinusoidal oscillator may be regarded as a positive-feedback amplifier with a filter in the feedback loop. This filter—normally a tuned circuit or a tuned transformer—permits little loop gain at the harmonic frequencies. By-passing the filter with an all-pass network will increase the gain at harmonic frequencies; however, if this process is carried too far, the tuned circuit will lose control of the operating frequency, and relaxation oscillations will be produced.

As an example, consider the cathode-coupled oscillator[10–12] shown in Fig. 1(a). With proper design, a sine

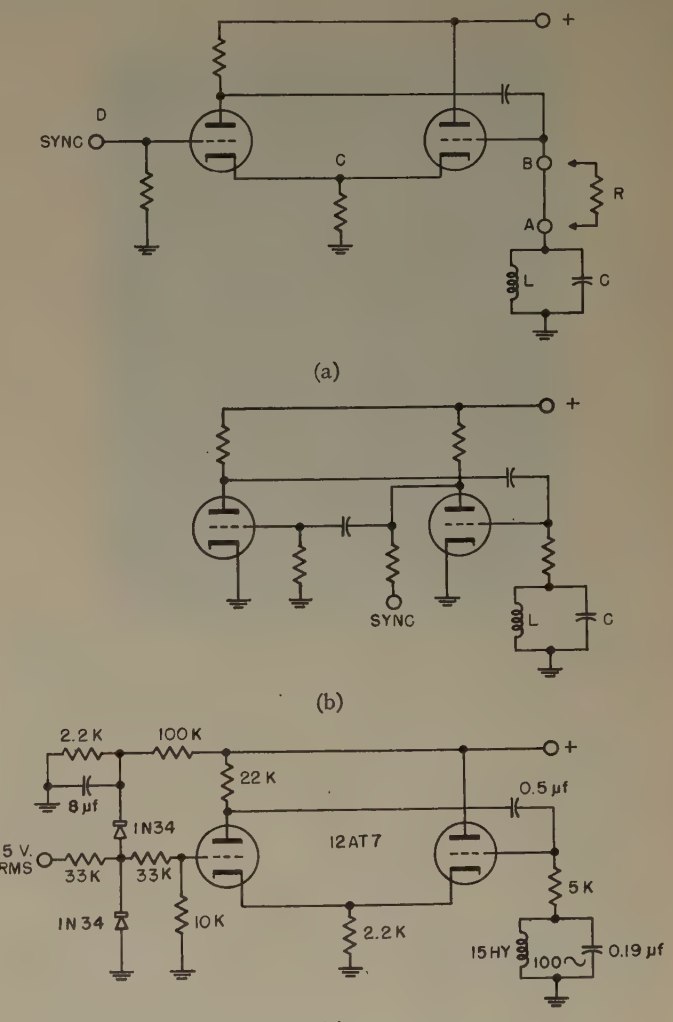

Fig. 1—Locked-oscillator frequency dividers.

* Decimal classification: R213.2×R357.3. Original manuscript received by the Institute, November 22, 1950; revised manuscript received, March 13, 1951.

† National Bureau of Standards, Washington, D.C.

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[2] E. Normann, "The inductance-capacitance oscillator as a frequency divider," PROC. I.R.E., vol. 24, pp. 799–803; October, 1946.
[3] C. R. Schmidt, "Frequency division with phase-shift oscillators," *Electronics*, vol. 23, pp. 111–113; June, 1950.
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[5] R. L. Miller, "Fractional frequency generators utilizing regenerative modulation," PROC. I.R.E., vol. 27, pp. 446–457; July, 1939.
[6] L. M. Hull and J. K. Clapp, "A convenient method for referring secondary frequency standards to a standard time interval," PROC. I.R.E. vol. 17, pp. 252–271; February, 1929.
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[10] M. G. Crosby, "Two terminal oscillator," *Electronics*, vol. 19, pp. 136–137; May, 1946.
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wave is produced at points A and B, while a half-sine wave is produced at C. Hence harmonics are present, and frequency division by factors of two or three is possible if sufficient synchronizing voltage is inserted at point D. It is found, however, that there is little tendency for stable operation at larger frequency ratios, indicating, from the above, a possible need for greater high-order harmonic content.

A simple way of increasing the loop gain at harmonic frequencies is to insert a resistance R at points A and B. As the value of R is increased, a sine wave continues to be produced at A, but rapid transitions are obtained in the wave form at B, indicating the presence of the desired high-order harmonics. With a moderate value of R, the tuned circuit LC retains control of the oscillator frequency. As R is increased, however, a critical point is reached at which relaxation oscillations are obtained. The oscillograms of Fig. 2, taken from the circuit of Fig. 1(c), show this process.

Fig. 2—Oscillograms showing the voltage at point B for the following conditions: (a) $R=0$; (b) $R=3{,}000$ ohms; (c) $R=10{,}000$ ohms; (d) $R=11{,}000$ ohms (relaxation oscillations—sweep frequency was decreased by factor of 10); (e) $R=0$, with 5 volts peak-to-peak applied to point D; (f) $R=10{,}000$ ohms, same synchronizing voltage.

With an intermediate value of R, excellent locking is obtained and stable frequency division by large integers is possible. At the same time, division by rational numbers is observed. Thus an output at 60 cycles can be obtained with an input of 100 cycles, or 50 cycles can be obtained from 60 cycles. The optimum value of R for this or any other condition is best determined by experiment. It appears to be a function of the frequency ratio, the impedance presented by the negative-resistance circuit, and the resonant impedance and Q of the tuned circuit. In any case, the setting of R is a compromise; harmonic content sufficient for locking is required, but excessive harmonic content may decrease the frequency stability of the oscillator to such an extent that synchronization is lost.

A second feedback oscillator[13] that is capable of being modified for frequency division is shown in Fig. 1(b). It is possible that the transitron[14] and screen-coupled[15] oscillators might also be useful in this application. The use of single-tube, transformer-coupled oscillators has not been considered, although a wide-band transformer might permit the use of this type of circuit.

Circuit Performance

Although it may be difficult to establish a criterion for judging the reliability of the circuit, measurement of the plate-supply-voltage range over which locking occurs at a desired frequency ratio appears to be a reasonable choice. Thus the circuit of Fig. 1(c), when dividing by 10, will lock as the plate supply is varied from 26 to 350 volts. This compares favorably with the range of 180 to 350 volts obtained with a well-designed astable multivibrator operating at the same frequency ratio.[16]

One requirement of the modified locked oscillator is that the synchronizing voltage be made proportional to

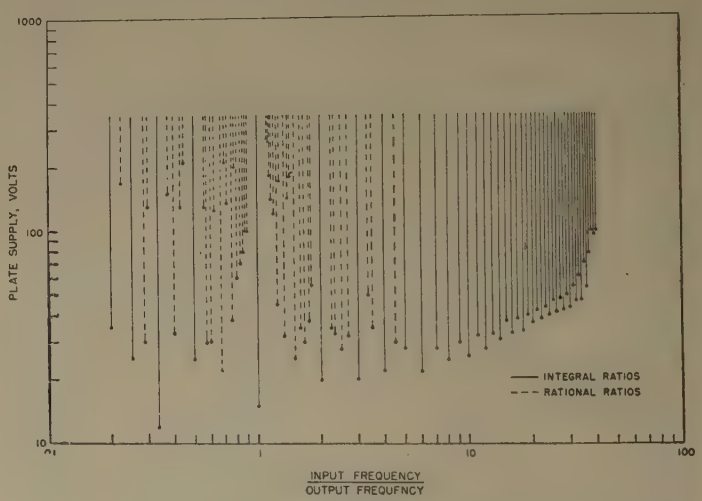

Fig. 3—Plate-supply-voltage range over which locking was obtained versus frequency ratio. Solid lines indicate integral ratios; dashed lines indicate rational frequency ratios.

the plate-supply voltage. This is accomplished in Fig. 1(c) by means of a biased clipper. Such clippers are not required between stages when several dividers are connected in a chain.

Fig. 3 shows the performance of the circuit of Fig. 1(c) at many different frequency ratios. Here the vertical-line length indicates the plate-voltage range over which locking was obtained at the frequency ratio shown by the horizontal scale. It will be noted that synchronization was obtained at frequency ratios from

[13] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Co., Inc., New York, N. Y., p. 509; 1943.
[14] C. Brunetti, "The transitron oscillator," Proc. I.R.E., vol. 27, pp. 88–94; February, 1939.
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[16] B. Chance, "Waveforms," McGraw-Hill Book Co., Inc., New York, N. Y., p. 577; 1949.

1/5 to 40. If a plate-supply voltage range of 7-to-1 is taken as indicative of reasonably good stability, frequency ratios up to 30 are possible.

It is worth mentioning that the circuit under consideration divided by 10 with a wide range of type 12AT7 tubes. In addition it functioned with other tube types, including the 12AU7, 12AX7, 6SN7GT, and 6SL7GT, without readjustment. Although long-time tests have not been completed, this is believed to be an indication that a long effective tube life will be obtained, barring accidents such as open heaters or short circuits.

Design and Adjustment

In designing locked oscillators for use as frequency dividers it appears to be necessary to employ empirical methods; however, the following suggestions may be found helpful:

1. The negative-resistance circuit employed should be designed to present the lowest possible value of negative resistance[17] consistent with the available plate-supply voltage and desired plate dissipation. This will aid in obtaining a rapid transition, which will produce high harmonic content.

2. It has been found by experiment that the optimum tuned-circuit Q is approximately equal to the frequency ratio employed, when the circuit is used as a frequency divider. A lower value of Q will produce poor frequency stability which may cause a loss of synchronization, while a much higher Q will make adjustment difficult, and will also result in a poor phase lock and restricted operating bandwidth.

The tuned circuit must contain linear elements. Molybdenum-permalloy inductors have been found very satisfactory. When very high inductances are required, nickel-iron alloy cores can be used if a sufficiently large gap is provided to stabilize the value of the inductance under conditions of changing flux density. If this precaution is not observed, variations in oscillation amplitude due to supply-voltage or tube changes may cause sufficient detuning to effect loss of synchronization.

In selecting the value of the inductance it is satisfactory to take product henrys × cycles (operating frequency) equal to 1,000. Deviations by factors of 1/3 to 3 from this rule will permit satisfactory results providing a sufficiently high Q can be obtained.

3. In aligning the circuit, a small synchronizing voltage is applied, and the resonant circuit is set for locking at the desired frequency ratio by means of a decade capacitor. The synchronizing voltage is then increased until the oscillator stops functioning. The optimum synchronizing voltage is approximately one half this value. If an excessive amount of synchronization is applied, oscillation will cease at low plate-supply voltage or with low-transconductance tubes.

Divider-Chain Example

The circuit of Fig. 4 is used to divide from 100 kc to 1 kc to obtain driving voltage for a 1-kc clock. Sine-wave and pulse outputs are provided for timing purposes.

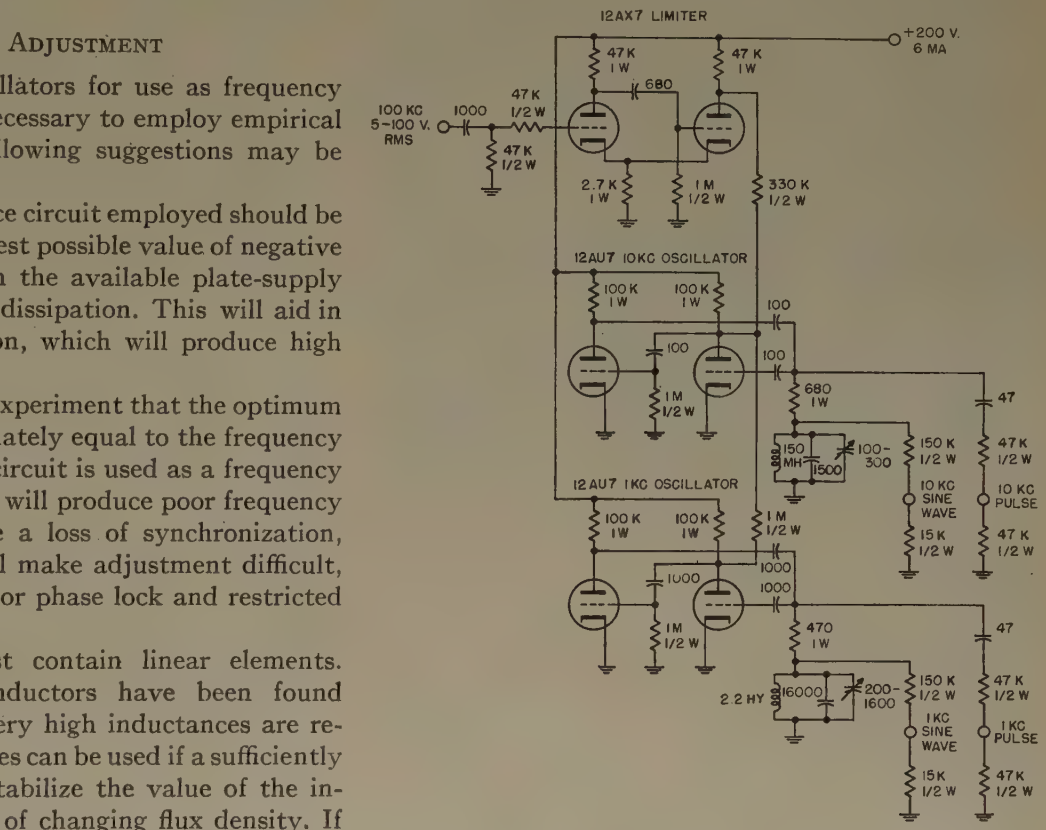

Fig. 4—Divider chain producing 10-kc and 1-kc sine waves and pulses from a 100-kc input. All capacitances in $\mu\mu$f. $K=10^3$. $M=10^6$.

The divider chain will operate properly as the plate supply is varied from 30 to 350 volts; at the same time, the heater supply can be varied from 2.8 to 12 volts.

The approach used in this paper has involved the modification of a sinusoidal oscillator; however, the same result can be obtained by considering the process as one of stabilizing a multivibrator by means of a tuned circuit. Builder[18] has described a successful gas-tube divider using resonant stabilization, although performance data were not given.

[17] P. G. Sulzer, "Cathode-coupled negative-resistance circuit," Proc. I.R.E., vol. 36, pp. 1034–1039; August, 1948.

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The Source of Long-Distance Backscatter*

WILLIAM G. ABEL†, AND LEONARD C. EDWARDS†, ASSOCIATE, IRE

Summary—**This paper describes a method of determining the source of the long-distance backscatter and the results obtained using this method at frequencies of 9, 12, 16, and 22 mc.**

Introduction

IN THE PAST there has been conflicting opinion among research workers in ionospheric physics as to whether the backscatter has its origin in the E region of the ionosphere or at the surface of the earth. Eckersley[1] concluded that all backscatter is from the E region. Benner,[2] and Hartsfield, Ostrow, and Silberstein[3] reported that long-distance backscatter is made up of both E region and ground scatter. Peterson[4] concluded that, in most cases, the backscatter is from the ground. It is the purpose of this paper to present a method for determining the source of long-distance backscatter, and to report the results of an investigation, using this method at frequencies of approximately 9, 12, 16, and 22 mc.

Description of Backscatter

Scattering of electromagnetic radiation occurs when it encounters irregularities along the path of propagation which are large compared to the wavelength. For frequencies above several mc such irregularities are found both at the surface of the earth and in the E region of the ionosphere.

If electromagnetic waves are transmitted at a frequency above the critical frequency of the F region for vertical incidence, the skip-distance ray will follow a path similar to ACE in Fig. 1. If the waves are scattered after reflection from the F region, either in the E region at $\overline{DD'}$ or on the ground at $\overline{EE'}$, some of the energy may be returned as the long-distance backscatter along path $\overline{DD'}\overline{C'C}A$ or path $\overline{EE'}\overline{C'C}A$.

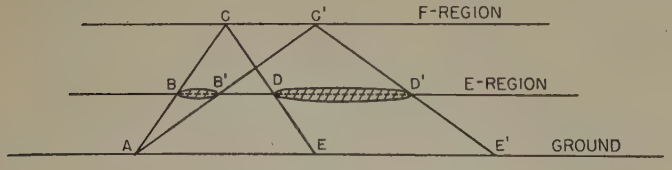

Fig. 1—Sources of backscatter.

Long-distance backscatter received at the transmitter and presented on an oscilloscope with a linear horizontal time sweep produces a pattern similar to that in Fig. 2. The transmitted pulse appears as a single pip

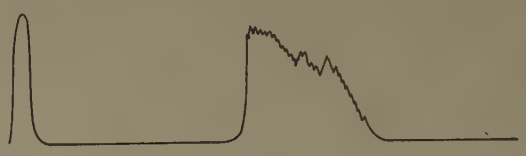

Fig. 2—A-scope presentation of backscatter pattern.

at the left of the trace; the backscatter pattern, as a succession of pips of slowly varying amplitude near the center.

Method of Determining Backscatter Source

For frequencies greater than about 1.5 times the vertical-incidence critical frequency of the F region, the leading edge of the backscatter pattern is made up of scatter produced by the skip-distance ray either in the E region at D or on the ground at E in Fig. 1. Delay time to the leading edge of the pattern is then a measure of propagation time between the transmitter and the near edge of the backscatter source, along either $ACDCA$ or $ACECA$. If a beacon transponder located at E were triggered by the skip-distance ray, delay time to the beacon response would be a measure of propagation time between the transmitter and the ground along the path $ACECA$.

Since the position of the beacon response, with reference to the leading edge of the backscatter pattern, can be measured accurately when displayed with suitable time markers on a linear oscilloscope trace, it is possible to determine whether the leading edge of the pattern is produced by the E region or the ground scatter. If the delay time to the beacon response and that to the backscatter pattern are equal, it is evident that the leading edge of the pattern is produced by the ground scatter at E. If, however, the delay time to the beacon response exceeds that to the backscatter pattern by the propagation time between the E region and ground along the path DED, it is equally evident that the leading edge of the pattern is produced by the E region scatter at D.

If the leading edge of the backscatter pattern is found to be produced by the ground scatter, the remainder of the pattern can also be expected to be produced by the ground scatter. If the leading edge is produced by the E region scatter, then the remainder of the pattern can be expected to be produced by both the E region and the ground scatter. The reason for this is clear from the geometry of the propagation path when we remember that scatter is produced when electromagnetic radiation

* Decimal classification: R113.242.2. Original manuscript received by the Institute, November 20, 1950; revised manuscript received, March 16, 1951.

† Raytheon Manufacturing Company, Waltham, Mass.

[1] T. L. Eckersley, "Analysis of the effect of scattering in radio transmission," Jour. *IEE* (London), vol. 86, pp. 548–563; June, 1940.

[2] A. H. Benner, "Predicting maximum usable frequency from long-distance scatter," Proc. I.R.E., vol. 37, pp. 44–47; January, 1949.

[3] W. L. Hartsfield, S. M. Ostrow, and R. Silberstein, "Backscatter observations by the central radio propagation laboratory—August, 1947 to March, 1948," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 199–214; February, 1950.

[4] A. M. Peterson, "The interpretation of long scatter echo patterns," *Proc. Conf. Ionospheric Res.*, vol. 1, pp. 1F–11F; June, 1949.

encounters irregularities which are large compared to the wavelength. The vertical angle of arrival of waves arriving in $\overline{DD'}$ (Fig. 1) decreases from D to D'. The effective size of the irregularities parallel to the wave front will also decrease with the decreasing angle so that, at the low angles of arrival, there will be less tendency for scatter production in the E region than at the higher angles. If the skip-distance ray does not produce the E-region scatter but penetrates this region to produce scatter at the ground, there is no reason to believe that waves arriving in the E region at lower angles will produce the E-region scatter. In this case the entire backscatter pattern is produced by the ground scatter. However, if the skip-distance ray does produce scatter in the E region, some of the energy will be scattered in a forward direction and form scatter at the ground. Waves arriving in the E region at lower angles than those of the skip-distance ray, and producing the E-region scatter, will also penetrate to the ground to produce ground scatter. Under these circumstances, the leading edge of the backscatter pattern is produced by the E-region scatter, the remainder of the pattern by a combination of the E region and the ground scatter.

If a beacon transponder is located beyond the minimum skip distance for the operating frequency, the distance to the transponder will become the skip distance twice during the day: in the morning as the skip distance decreases, and in the evening as it increases. Thus, two records per day are obtained when the delay time to the leading edge of the backscatter pattern can be compared with that to the beacon response. In this investigation, four transponders located at distances of approximately 700, 1,000, 1,500, and 2,000 miles from the transmitter, were used.

Equipment

The equipment of the transmitting station consisted of a pulse transmitter, a Hammarlund Super-Pro receiver modified for pulse reception, and timing and recording equipment. The transmitter was operated at approximately 20-kw peak-power output, using 100-microsecond pulses at a repetition rate of 20 pulses per second. The output from the receiver was displayed in two different ways on two separate oscilloscopes, one an A-scope presentation with time markers for monitoring and photographing and the other with an intensity-modulated time base for continuous photographic recording. Three-element Yagi antennas were used at frequencies of 9, 12, and 16 mc, and a five-element Yagi antenna at 22 mc.

Each beacon transponder comprised a pulse receiver and a pulse transmitter operated at a peak-power output of 1 kw. A delay of 1 millisecond was inserted in the beacon between the arrival of the first interrogating pulse and the beacon response. The antennas used with the beacons were vertical whips for the 9- and 12-mc frequencies and horizontal half-wave dipoles at a half-wave above ground for the 16- and 22-mc frequencies.

Analysis of Data

From the continuous, intensity-modulated film records, measurements were obtained of the difference in delay time between the leading edge of the backscatter pattern and the beacon response for all times when a transponder was at the skip distance. These times were readily identified on the film by the converging of the high- and low-angle rays of the beacon response prior to fadeout, and the diverging of these rays following the first reception of the beacon response. A typical film record of the backscatter pattern and the beacon response when a transponder is at the skip distance is shown in Fig. 3. In this case, the distance from the transmitter to the transponder is approximately 1,000 miles. As the high- and low-angle rays converged, the

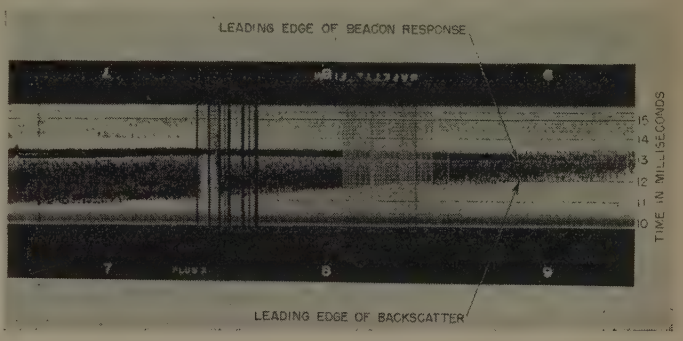

Fig. 3—Intensity-modulated film record of backscatter pattern and beacon response.

delay time to the leading edge of the backscatter pattern increased. At the moment when the beacon response faded out because of the skip distance increasing beyond the distance to the transponder, it was approximately 1 millisecond ahead of the beacon response. Since one millisecond of delay was inserted at the transponder between the triggering signal and the beacon response, the delay time to the beacon response is actually the same as that to the leading edge of the backscatter pattern. Therefore, the backscatter in this case is from the ground, the leading edge of the pattern being produced by scatter at the skip distance, and the remainder of the pattern by scatter at greater distances.

Fig. 4 (see page 1540) shows the various differences in delay time measured between the leading edge of the backscatter pattern and the beacon response when a transponder was at the skip distance, and the number of times each measurement was obtained during operation on all frequencies. The large number of times when the difference in delay time was approximately equal to the inserted 1-millisecond beacon delay clearly indicates that in the majority of cases backscatter was from the ground.

To determine whether there were any instances of E-region scatter, in all cases where the delay time between the leading edge of the backscatter pattern and the beacon response was greater than 1 millisecond, the measured delay time was compared with the delay time required for E-region scatter, i.e., propagation time between E region and ground plus 1 millisecond of delay.

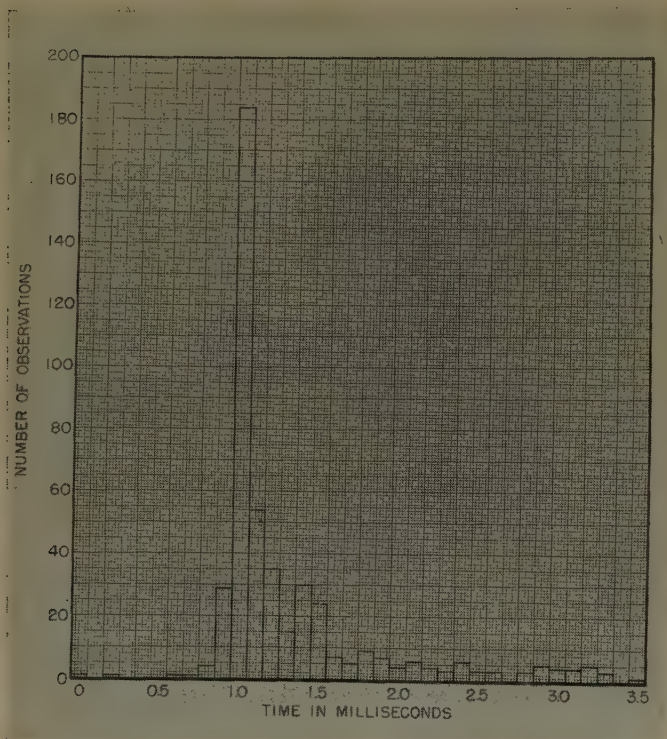

Fig. 4—Delay time between leading edge of backscatter pattern and beacon response averaged for 9, 12, 16, and 22 mc.

The differences between the measured delay time between the leading edge of the backscatter pattern and the beacon response, and the time difference required for *E*-region scatter and the number of times each difference was obtained, are shown in Fig. 5. The few cases where the differences were approximately zero shows that they are probably random cases and not cases of *E*-region scatter.

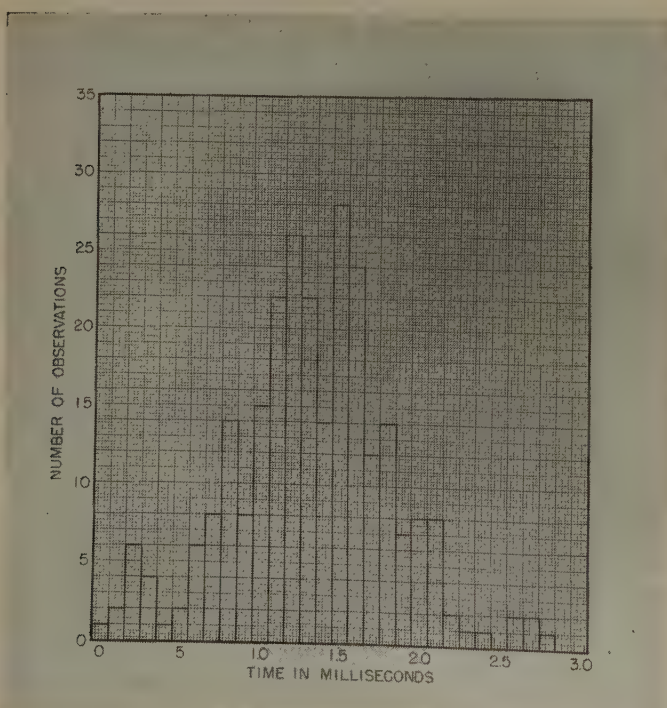

Fig. 5—Difference between measured delay time and delay time required for *E*-region backscatter averaged for 9, 12, 16, and 22 mc.

Since delay times between the leading edge of the backscatter pattern and the beacon response greater than 1 millisecond could not be attributed to *E*-region scatter, the reason for these delay time was further investigated. In most such cases the backscatter pattern on the intensity-modulated film was found to have a somewhat ragged leading edge. This ragged edge corresponds to slowly varying, low-amplitude pips in the pattern displayed on a linear oscilloscope trace. It was also noted that with the antenna pointed at the transponders, and a pattern of low-amplitude pips at the the leading edge followed by an amplitude peak at some distance, this amplitude peak could be moved to the leading edge of the pattern, with no change in delay time to the leading edge, merely by rotating the antenna slightly to the south. This is illustrated in Figs. 6a and 6b. Fig. 6a is an A-scope picture taken with the antenna pointing toward the transponder sites, and Fig. 6b one with the antenna directed approximately

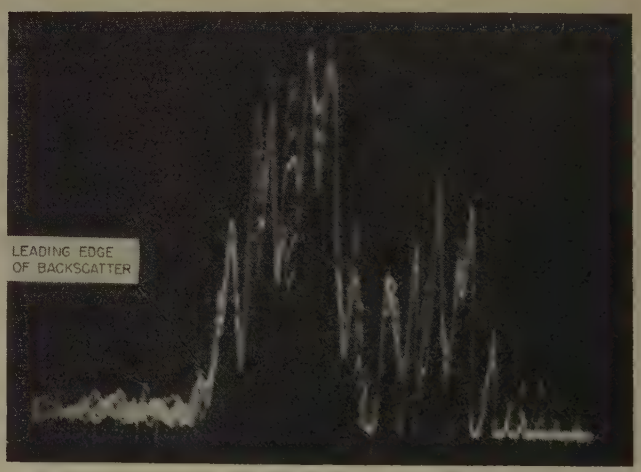

Fig. 6(a)—A-scope presentation of backscatter on 22 mc at azimuth of transponders.

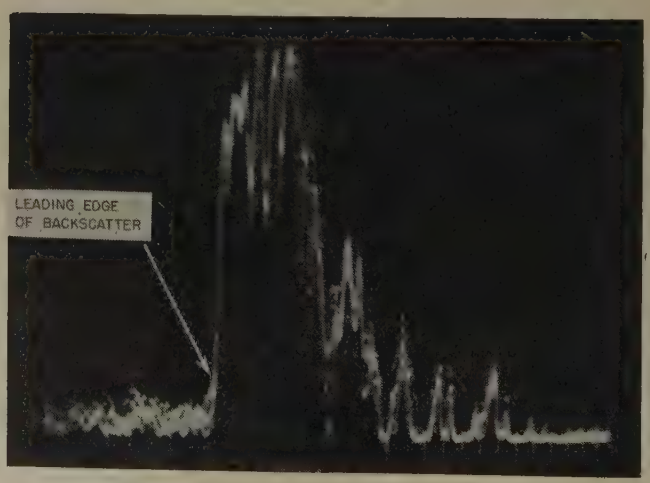

Fig. 6(b)—A-scope presentation of backscatter on 22 mc 30 degrees south of azimuth of transponders.

30 degrees to the south of the first position. The weak leading edge of the pattern in Fig. 6a is from the same source as the strong leading edge in Fig. 6b. It is weaker in the first picture because the backscatter producing this portion of the pattern is arriving at an angle of approximately 30 degrees to the principal axis of the antenna. The arrival of the backscatter from azimuths off the principal axis of the antenna ahead of that along the principal axis masks the true leading edge of the backscatter pattern, particularly on intensity-modulated film. This low-amplitude backscatter at the leading edge of the pattern explains many of the cases shown in Fig. 4, where the delay time between the leading edge of the backscatter pattern and the beacon response was greater than 1 millisecond.

Conclusions

The amplitude peak, either at the leading edge of the backscatter pattern or slightly behind it, is produced by ground scatter at the skip distance measured along the principal axis of the antenna; that portion of the pattern following this peak, by ground scatter beyond the skip distance. Delay time to this peak is therefore a true measure of slant range to the skip distance.

That portion of the backscatter pattern ahead of this amplitude peak is produced by backscatter from azimuths off the principal axis of the antenna, and at shorter distances, arriving ahead of backscatter along the principal axis.

Acknowledgment

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Space-Charge and Ion-Trapping Effects in Tetrodes*

KARL G. HERNQVIST†

Summary—**Under the assumption of absolute vacuum in a tetrode, the space-charge depression in the screen-grid anode region will at sufficiently high current prevent secondary electrons released at the anode from reaching the grid, thus making the anode-current, anode-voltage characteristic similar to that of a pentode. Under pressure conditions present in ordinary high-vacuum tubes, positive ions formed by collisions between electrons and residual gas molecules will be trapped in the potential trough between the screen grid and the anode. Provided there exists no transverse ion-sweeping fields from beam-forming plates (as in the beam-power tetrode) or from charged end insulators, ion trapping proceeds automatically until the electron charge is neutralized. The effects of ion-trapping are discussed and a pulse method is described for measuring the conditions with and without presence of ions and for studying the ion-buildup process. Plasma ion oscillations have been observed.**

I. Introduction

An ION TRAP is defined as such a region in an electron flow where the space-charge field of the electrons, together with the primary electrostatic field, acts as a potential trough for positive ions. If the electron velocity is above the ionization potential, such a trough will be filled with ions formed by collisions between electrons and residual gas molecules. This trapping process will proceed automatically until the electron charge is neutralized, the equilibrium condition being determined by such factors as rate of formation of ions and ion temperature. Even at pressures used in ordinary high-vacuum tubes the number of residual gas molecules will be sufficient to supply ions for electron flow of high current density. The trapping of ions in electron beams, observed through its effect on the beam spread, has been studied by Field, Spangenberg and Helm,[1] and by Linder and Hernqvist.[2] However, it seems that the effect has not been studied for other types of electron flow.

The space-charge effect in the grid-anode region of vacuum tubes has been studied both theoretically and experimentally by several workers. Here will only be mentioned the well-known papers by Plato, Kleen, and Rothe,[3] Fay, Samuel, and Shockley,[4] and Salzberg and Haeff.[5] Conditions for ion trapping sometimes occur in such a grid-anode region. However, for reasons discussed below, this effect appears not to have been observed.

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[1] L. M. Field, K. Spangenberg, and R. Helm, "Control of electron beam dispersion at high vacuum by ions," *Elec. Commun.*, vol. 24, pp. 108–121; March, 1947.

[2] E. G. Linder and K. G. Hernqvist, "Space-charge effects in electron beams and their reduction by positive ion trapping," *Jour. Appl. Phys.*, vol. 21, pp. 1088–1097; November, 1950.

[3] G. Plato, W. Kleen, and H. Rothe, "Die Raumladegleichung für Elektronen mit Anfangsgeschwindigkeit," *Zeit. für Phys.*, vol. 101, pp. 509–520, 1936; and Nos. 11, 12, pp. 711–723, 1937.

[4] C. E. Fay, A. L. Samuel, and W. Shockley "On the theory of space charge between parallel plane electrodes," *Bell Syst. Tech. Jour.*, vol. 17, pp. 49–79; January, 1938.

[5] B. Salzberg and A. V. Haeff, "Effects of space charge in the grid anode region of vacuum tubes," *RCA Rev.*, vol. 2, pp. 336–374; January, 1938.

II. Effects of Space Charge and Secondary Emission in the Grid-Anode Region of Tetrodes

In this section the conditions will be discussed under the assumption of absolute vacuum. A brief summary of some of the results obtained in the above-mentioned papers[3–5] will be given.

Consider a parallel stream of electrons being injected into a plane-parallel grid-anode space, the electrodes at first being assumed to yield no secondary electrons. Fig. 1 is a plot of the corresponding potential distribution. Here curve 1 represents the electric field without presence of electrons. Due to the space charge of the electrons, the potential will be decreased as shown by curve 2. Increasing the injected current will further decrease the potential, and for sufficiently high current a potential minimum V_m will be formed, as at 3. However, this depression will not affect the current to the anode; only the transit time of the electrons when passing from G to A will be increased. But when

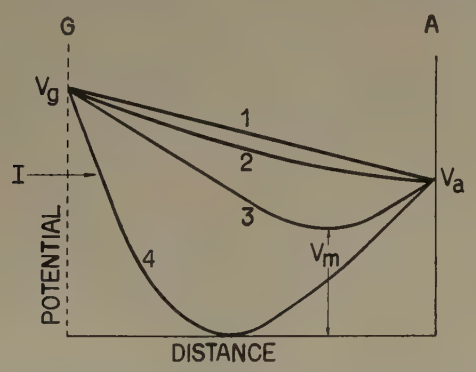

Fig. 1—Potential distributions in a plane-parallel grid-anode space as the injected current is varied.

the injected current is further increased, there will be a certain current at which there is an abrupt decrease in the anode current. This corresponds to a sudden drop to zero in the value of the potential minimum. A so-called virtual cathode has been formed. Some electrons will be reflected to the grid, causing a current partition and an anode-current versus injected-current characteristic with the well-known hysteresis effect. The anode current just before formation of the virtual cathode is the maximum current that can be transmitted through the grid-anode region. It is determined by

$$(I_a)_{\max} = 2.33 \times 10^{-6} \times \frac{(V_g^{1/2} + V_a^{1/2})^3}{a^2} \times S \text{ amperes}, \qquad (1)$$

where V_g and V_a are the grid and anode voltages, respectively, a is the distance between grid and anode, and S is the area of the electron flow.

Now consider the practical case when the anode A is a secondary-electron-emitting surface. Fig. 2[6] is an example of a current-energy distribution of the secondary electrons emitted by such a surface. Curves for

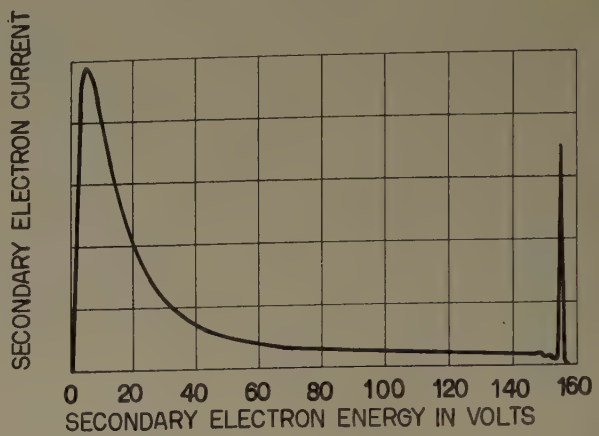

Fig. 2—Current-energy distribution of the secondary electrons emitted by gold at a primary electron energy of 155 volts.

other primary electron velocities and other materials are similar in shape, having a maximum at about 2 to 6 volts, practically independent of the primary electron velocity. If the anode voltage is equal to or less than the grid voltage, secondary electrons from the anode will enter the grid-anode region and their space charge will influence the potential distribution curve of the primary electrons shown in Fig. 1. To determine quantitatively the resulting potential distribution curve would be almost impossible. If there is a depression in the resulting potential distribution, only a part of the secondary electrons whose velocity distribution is determined by a relation similar to that of Fig. 2 will overcome the retarding potential. Introducing the following symbols,

I = current injected into the grid-anode space
I_a'' = secondary electron yield of the anode
$(I_a'')_{\text{refl}}$ = the part of I_a'' that will not overcome the retarding space-charge potential at the anode
I_a = resulting anode current
$\delta = I_a''/I$ = ratio of secondary- to primary-electron currents of the anode,

one obtains the current measured in the anode circuit

$$I_a = I - I_a'' + (I_a'')_{\text{refl}} \qquad (2)$$

or

$$\frac{I_a}{I} = 1 - \delta + \frac{(I_a'')_{\text{refl}}}{I}. \qquad (3)$$

Here $(I_a'')_{\text{refl}}$ will be determined by the depth $(V_a - V_m)$ of the potential depression. For small currents there will be no space-charge potential depression; most of the secondaries will reach the grid and I_a/I will approach the value $1-\delta$. If the injected current is increased, more and more of the secondaries will be reflected back to the anode, and, finally, for high currents none of the

[6] E. Rudberg, "Inelastic scattering of electrons from solids," *Phys. Rev.*, vol. 50, pp. 138–150; July 15, 1936.

secondary electrons will overcome the potential depression, thus making $I_a/I=1$. For still higher currents I_a will reach its maximum value, and finally a virtual cathode will be formed as discussed above. Due to the space charge of the secondaries, the value of $(I_a)_{max}$ will probably be somewhat decreased, compared to the value set by (1).

The results of the above discussion can be transferred to the anode current-anode voltage characteristics of a tetrode as shown in Fig. 3. Here, it is assumed that the conditions for formation of a virtual cathode, determined by (1), are not reached anywhere, and that there is no secondary-emission current from the screen grid. It is seen that for small currents the curves show the well-known dip due to the secondary-emission yield of the anode. However, for reasons discussed above, the dip disappears at high currents and the characteristics will be similar to that of a pentode.

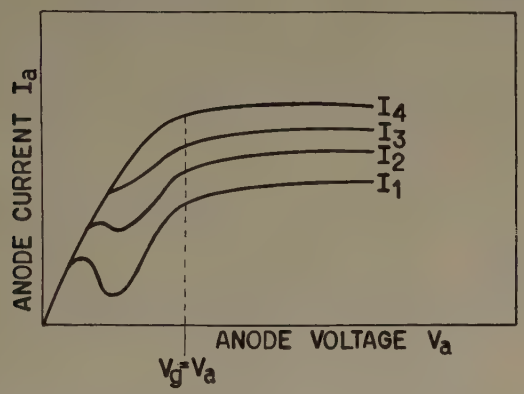

Fig. 3—Anode current-anode voltage characteristics of a tetrode under the assumption of absolute vacuum. Parameter is the current I injected into the screen-grid anode region. $I_1<I_2<I_3<I_4$.

III. Ion Trapping and Its Effects on Space Charge and Secondary-Emission Currents

The discussions of this section will be applied to the practical conditions in an ordinary high-vacuum tube with the presence of residual gas molecules.

Assuming the electron flow discussed in the previous chapter to be infinitely wide, or that there exists no ion-sweeping fields transversal to the direction of the electron flow, conditions for ion trapping are present when the electron velocity is above the ionization potential. The ideas and results obtained in the investigation of ion-trapping effects in electron beams[1,2] are, in general, applicable, even to the type of flow discussed here. In the beam type of flow, positive ions formed by collisions between electrons and residual gas molecules will be attracted to the beam axis, due to the depression in the *transversal* potential distribution of the beam. The same process will occur for conditions such as those present in curves 3 and 4 in Fig. 1, the trapping here being due to the depression in the potential distribution *along* the electron flow. The equilibrium conditions, however, will be somewhat different. Also, the behavior is not so well adaptable to numerical calculations as in the beam case.

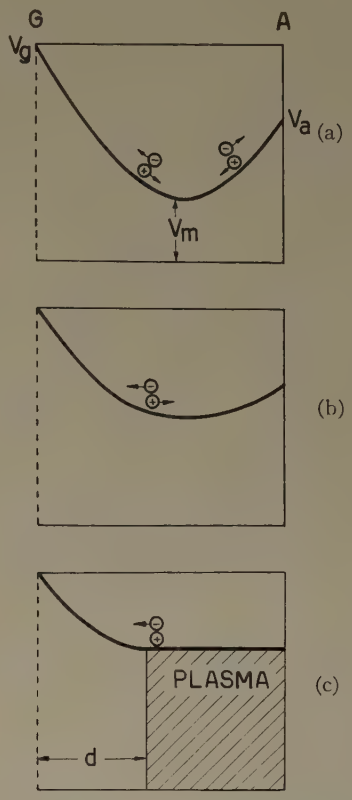

Fig. 4—Potential distributions in a grid-anode space with various degrees of space-charge neutralization.

For a better understanding of the behavior, different steps in the ion-trapping process have been indicated in Fig. 4 for the case discussed in Fig. 1. In Fig. 4(a) the potential distribution is shown for the unneutralized case when the electron flow is just injected. As shown by the arrows, positive ions will be attracted to the potential minimum. Low-velocity electrons formed in the ionization process will be pushed away from the depression. After some time part of the space charge will be neutralized by the trapped ions, and the potential will be increased as shown in Fig. 4(b). Finally, all the space charge in the trough will be neutralized and equilibrium conditions as in Fig. 4 (c) will be reached. Here a plasma region has been formed close to the electrode with lowest potential. The electrode with higher potential is surrounded by a sheath of unneutralized electron flow, the sheath-thickness d being determined by the Poisson equation and the boundary conditions. The boundary conditions are that the potentials V_1 and V_2 at the electrodes, and the electric field strength be zero at the transition to the plasma region. For an injected current density J amperes per

[7] E. G. Linder, "Sheath formation in ion-neutralized electron beams," *Phys. Rev.*, vol. 80, pp. 99–100; October 1, 1950.

square cm, one obtains[3,7] if $V_1 > V_2$

$$d = 1.53 \times 10^{-3} \times \sqrt{\frac{1}{J}}\sqrt{\sqrt{V_1} - \sqrt{V_2}}\,(\sqrt{V_1} + 2\sqrt{V_2})\ \text{cm}. \quad (4)$$

The ion buildup time, i.e., the time required for the ion trap to be completely filled, has been calculated by Linder and Hernqvist.[2] If the electron velocity is determined by the voltage V, one obtains the ion buildup time measured in microseconds as

$$\tau = \frac{0.0169}{pP(V)\sqrt{V}}, \quad (5)$$

where p is the pressure in mm of mercury and $P(V)$ is the ionization probability in number of ions formed per cm per electron at a pressure of 1 mm of mercury. Here V is assumed to be constant during the ion buildup period, and the formula does not account for the fact that the potential is increased when space-charge neutralization takes place (e.g., from V_m to V_a for the sheet at the potential minimum in Fig. 4). However, in the practical case the errors caused by other effects will be much larger.

The practical effects of the ion trapping will be:

(1) The transit time of the electrons when passing from G to A will be decreased.

(2) The formation of a virtual cathode will be prevented.

(3) The secondary-emission currents will be influenced.

Transit-time effects will have significance under high-frequency operation, but will not be discussed further here.

Due to ion trapping, *a virtual cathode can exist only under certain conditions* although the limit set by (1) is surpassed. Either of the following conditions must be fulfilled: (a) the electron velocity is below ionization potential; or (b) there exists an ion-sweeping transversal field or certain types of pulsed and ac conditions.

Rothe, Plato, and Kleen[3] proved the existence of a virtual cathode under condition (a). In a beam-power tetrode a virtual cathode can be formed because of the ion-sweeping transversal field from the beam-forming plates. Salzberg and Haeff[5] verified experimentally in a specially built tube the existence of a virtual cathode. However, since no detailed information of the structure is given, it can only be supposed that transverse ion-sweeping fields from charged insulators have existed. If none of the above conditions is present, there will be no such limit for the current that can be passed through an interelectrode space as set by (1).

In the practical case when the anode is emitting secondary electrons, as discussed in connection with Fig. 3, the ion trapping will have a noticeable effect on the current distribution. After space-charge neutralization, as in Fig. 4(c), most of the secondary electrons from the anode will reach the grid. If the value of the anode current under space-charge neutralized conditions is $(I_a)_{SCN}$, the relation (3) will become

$$\frac{(I_a)_{SCN}}{I} = 1 - \delta. \quad (6)$$

Also, all of the anode current-anode voltage characteristics will show the typical dip, independent of the injected current.

From what is said above, the ways of indicating ion trapping are very limited although such effects may be quite common in vacuum tubes. Studying these effects in connection with the formation of a virtual cathode will be rather difficult because of the excessive heating of the grids at the high current density required. Studies of the effects on secondary-emission currents, described below, are limited to voltages where transfer of secondary electrons from one electrode to another is actually secured.

IV. Experimental Verification

A. Method of Measurements

The tube used in the tests (Fig. 5) is a commercial high-power transmitting tetrode, QB 2.5/250 made by Philips.[8] It is an all-glass tube with powder glass base,

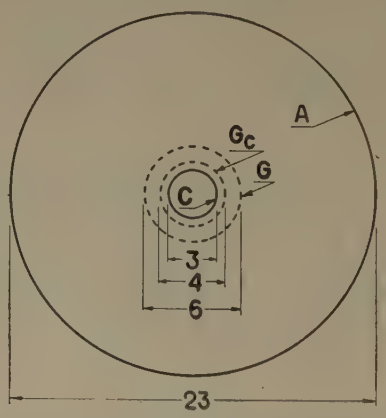

Fig. 5—Drawing showing the approximate dimensions in mm of the tetrode QB 2.5/250.

zirconium-coated carbon anode, molybdenum terminals, and a double helical thoriated tungsten filament. The screen-grid and the anode are supported directly by the terminals and no end insulators exist between these electrodes. Due to the treatment of the anode, the secondary emission has been brought to a minimum. On the other hand, the relatively long screen-grid anode distance, approximately 8.5 mm, has made the space-charge effects very pronounced, and therefore, this tube has been especially suitable for the measurements made here. The anode length is about 30 mm and the emitting cathode length about 25 mm.

In the tests, a pulse technique similar to the one

[8] The tube QB 2.5/250 was later followed by a somewhat modified type QB 3/300 (equivalent to the American-type 4-125A). A tube of this type was tested and showed the same effects as the QB 2.5/250. Since the function of this tube for anode voltages less than the screen-grid voltage is of little importance for the normal operation of the tube, no significant characteristics are given by the manufacturer in this voltage region. The tubes tested were perfectly satisfactory new ones.

used by Linder and Hernqvist[2] was applied. Fig. 6 is a circuit diagram showing the measurement arrangements. The pulser in the control-grid circuit produces a negative pulse of variable width and repetition rate,

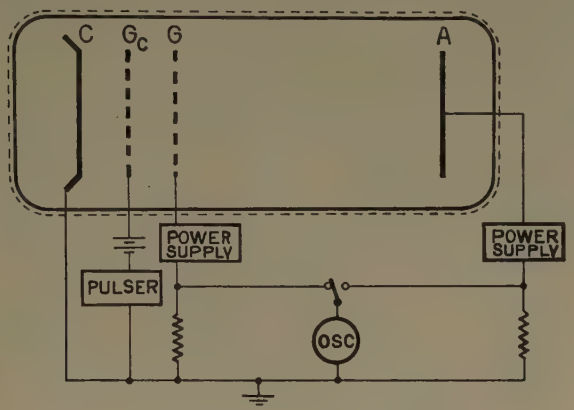

Fig. 6—Schematic diagram of tube and circuit.

and of a sufficiently high amplitude to cut off the cathode current. The oscilloscope could be connected to observe the screen-grid current or the anode current. A typical oscillogram is sketched in Fig. 7. Here control-grid voltage, screen-grid current, and anode current are plotted against time. From *a* to *b* are shown the equilibrium conditions with constant currents. At *b* a negative pulse is applied to the control grid of an amplitude high enough to cut off the currents and having a width great enough to allow trapped ions to be removed from the interelectrode spaces. At *e* the pulse is terminated, and the grid voltage as well as the cathode-emission current return to their initial values. The anode and screen-grid currents, however, do not immediately return to their equilibrium values. The anode current rises to a higher value, the screen-grid current to a lower. The reason for this is that the positive ions were removed during the application of the pulse and that there is no space-charge neutralization, and therefore, a depression is formed in the potential distribution as shown by curve 3 in Fig. 1. Consequently, some of the secondary electrons from the anode turn back and do not reach the screen grid. Thus the current at *e* represents the primary anode current minus the part of the secondary-emission current that can overcome the potential depression. If the depression is deep enough, all of the secondaries are reflected and the anode current at *e* is the primary current. However, in the interval from *e* to *f*, ions are again formed and trapped. At *f* the ion trap is completely filled, corresponding to a potential distribution shown in Fig. 4(c), and most of the secondaries from the anode will reach the screen-grid. Because of the current partition between screen grid and anode, the current to the former behaves as shown in Fig. 7(c). Fig. 8 shows an oscillogram of such a pulse, taken at $V_a = 200$, $V_g = 250$ volts, and a cathode-emission current $(I_a + I_g) = 115$ ma. The pulse length T_1 is 50 microseconds and the interval between pulses $T_2 = 2{,}000$ microseconds.

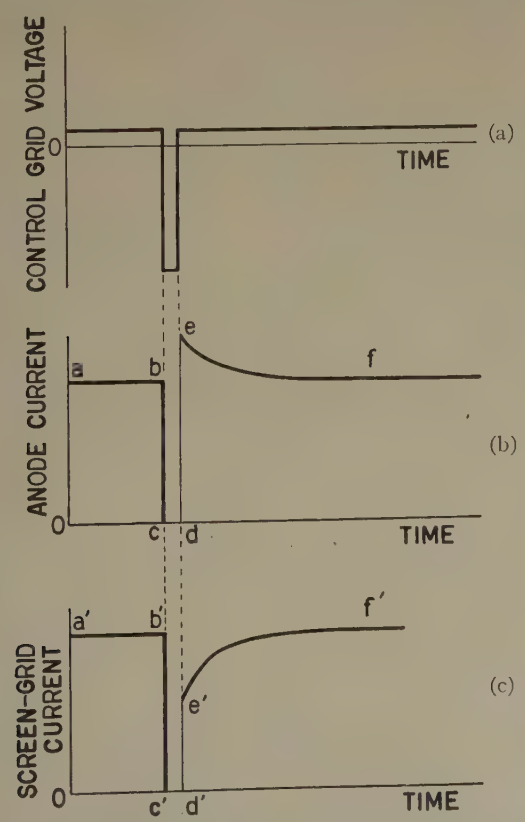

Fig. 7—Typical pulse shapes showing control-grid voltage (a), anode current (b), and screen-grid current (c).

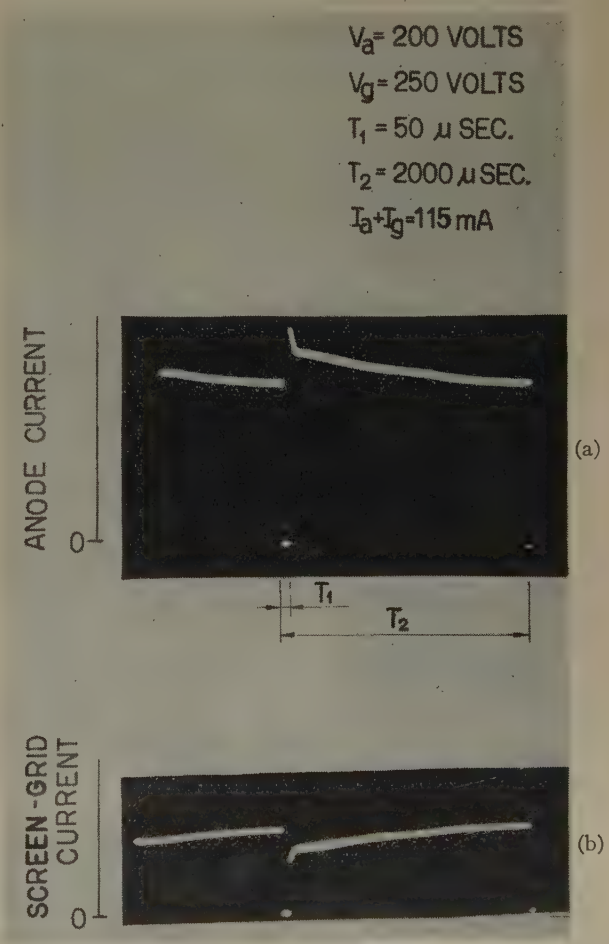

Fig. 8—Oscillogram of anode current (a) and screen-grid current (b).

B. Effects of Anode Voltage and Current Variation

Anode current-anode voltage characteristics of a tetrode without space-charge neutralization as discussed in Fig. 3, can be determined directly from oscillograms such as that of Figs. 7 and 8 (see page 1545). The ratio of the anode current without and with space-charge neutralization $I_a/(I_a)_{SCN}$ is the ratio of the lengths ed/bc. The numerical value of $(I_a)_{SCN}$ may be measured with a meter, while the pulser is switched off. The actual measurements were done on screen-grid oscillograms, such as that of Fig. 8(b), due to the better accuracy obtained here, the secondary-emission current from the anode being a bigger part of the screen-grid current. Since (I_a+I_g) was monitored and observed not to change its value after the pulse, the current represented by length $b'c'-e'd'$ equals that represented by $ed-bc$.

A series of oscillograms of the screen-grid current for different anode voltages are shown in Fig. 9. Here the grid voltages and the cathode-emission current (I_a+I_g) are kept substantially constant. For small values of the anode voltage, the secondary-emission current is small. When the anode voltage is increased, more and more secondaries are released from the anode, as indicated by the point e' moving downward. For anode voltages higher than the screen-grid voltage, again very few secondaries reach the screen-grid due to the retarding action of the primary electrostatic field. From such a series of oscillograms the corresponding anode current-anode voltage characteristics have been plotted in Fig. 10. Here is also shown the the value of $(I_a'')_{refl}$ which is the difference $I_a-(I_a)_{SCN}$. Obviously, the potential depression has not been high enough to prevent all secondaries from reaching the screen-grid, as indicated by the remaining incurved part of the I_a curve.

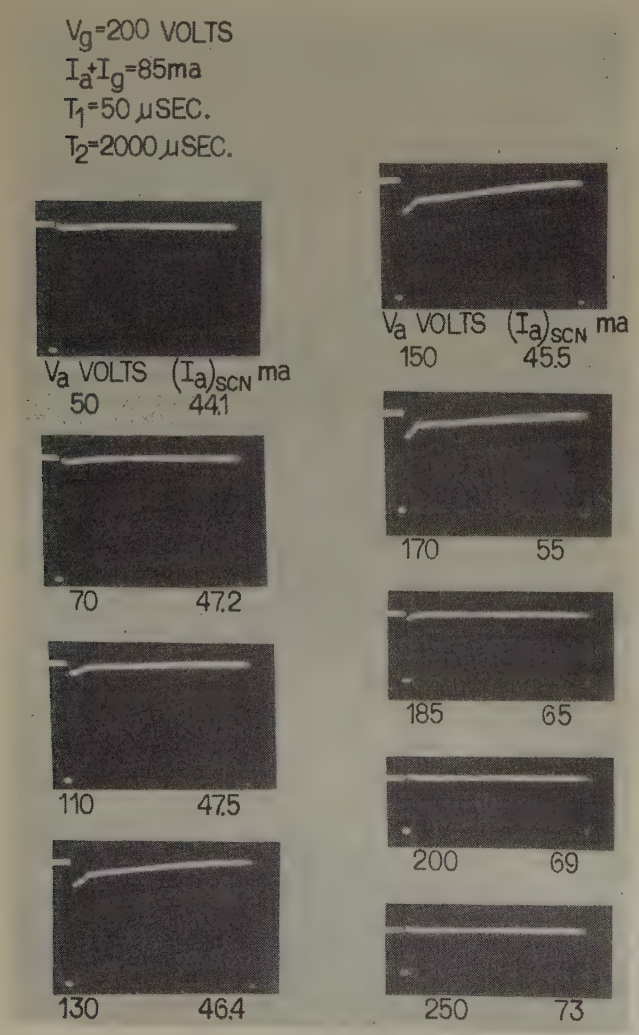

Fig. 9—Oscillograms of the screen-grid current showing the effect of varying anode voltage.

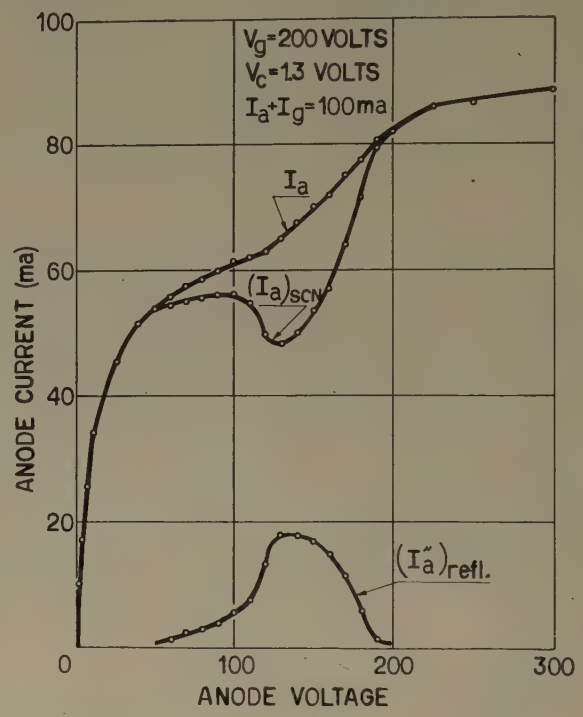

Fig. 10—Anode current-anode voltage characteristics with and without space-charge neutralization.

To show the effect of the injected current a number of anode current-anode voltage characteristics with the control-grid voltage V_c as parameter have been plotted in Fig. 11 (see page 1547). Here the filament current is kept constant and the injected current is varied by adjusting V_c. Along each of these characteristics (I_a+I_g) is substantially constant. It is seen how the dip in the I_a curve disappears at high injected currents.

C. Effect of Pressure Variation. Discussion of Pulse Shape.

Plasma Ion Oscillations: The tests described so far have been made on a sealed-off tube. Measurements of the ion current indicate that the data have been taken in a pressure region of approximately 10^{-6} to 5×10^{-6} mm of mercury.

The tube was put on a pumping system providing controlled adjustment of the pressure. A series of oscillograms of the screen-grid current for a range of pressures from 5.3×10^{-6} to 8×10^{-5} mm of mercury are shown in Fig. 12. The decrease in buildup time with increasing pressure, as required by the theoretical formula (6), is of an easily apparent magnitude in the

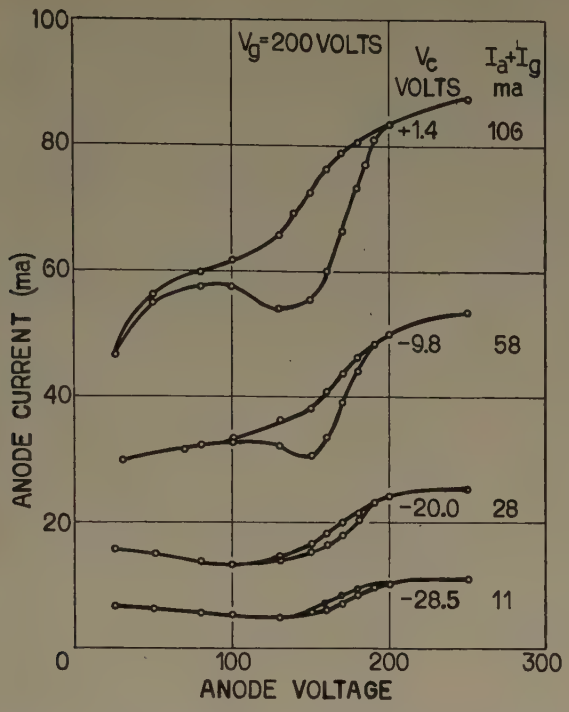

Fig. 11—Anode current-anode voltage characteristics with control-grid voltage as parameter.

photographs. As indicated in Fig. 12, there is a small decrease in the anode current $(I_a)_{SCN}$ under space-charge neutralized conditions when the pressure is increased. This effect may be explained in the following way. Due to the thermal velocities of the ions, there will be a tendency for the ions to escape from the trap. This loss of ions will have to be compensated by the formation of new ions. At low pressures, the rate of formation of ions is not as high as the rate of loss of ions would be for the field-free case in Fig. 4(c), and therefore there will have to be a remaining small potential depression ΔV_m between the screen grid and the anode to satisfy equilibrium conditions. When the pressure is increased, the rate of formation of ions also increases, and consequently ΔV_m decreases. At a sufficiently high pressure the rate of formation of ions will be equal to the rate of loss of ions under field-free conditions, and ΔV_m vanishes, as in Fig. 4(c). Thus the influence of ΔV_m on the low-velocity secondary electrons will account for the decrease in anode current with increasing pressure. These equilibrium conditions have been treated by Linder and Hernqvist.[2]

It is seen from the oscillograms, for instance that of Fig. 8(b), that the ion buildup takes place in two different steps. At first, the screen-grid current rises quite rapidly and with stability. Thereafter follows a discontinuous decrease in the rate of rise of the current accompanied by heavy irregular oscillations (barely visible on the photographs). The nature of these instabilities is not known for certain, but they are most likely caused by the low-velocity secondary electrons at the maximum in the current-energy distribution (Fig. 2). These electrons, which are the ones transmitted through the anode-grid region in the later part of the ion buildup process, represent a considerable space charge. The fact that these electrons mostly have velocities below the ionization potential of the residual gas molecules and do not contribute to the ion formation further increases the ion buildup time.

The unstable oscillations discussed above change to quite stable oscillations when the ion buildup is completed, and the ion density is approximately equal to the electron density. These oscillations can be synchronized with an oscilloscope or measured with a receiver. Oscillations were detected in the frequency region 0.5 to 1.5 mc. Comparison with the theory[9] for plasma ion oscillations indicated that the observed frequencies were of the right order of magnitude. Plasma ion oscillations in electron streams containing ions have been observed by other workers.[2,10]

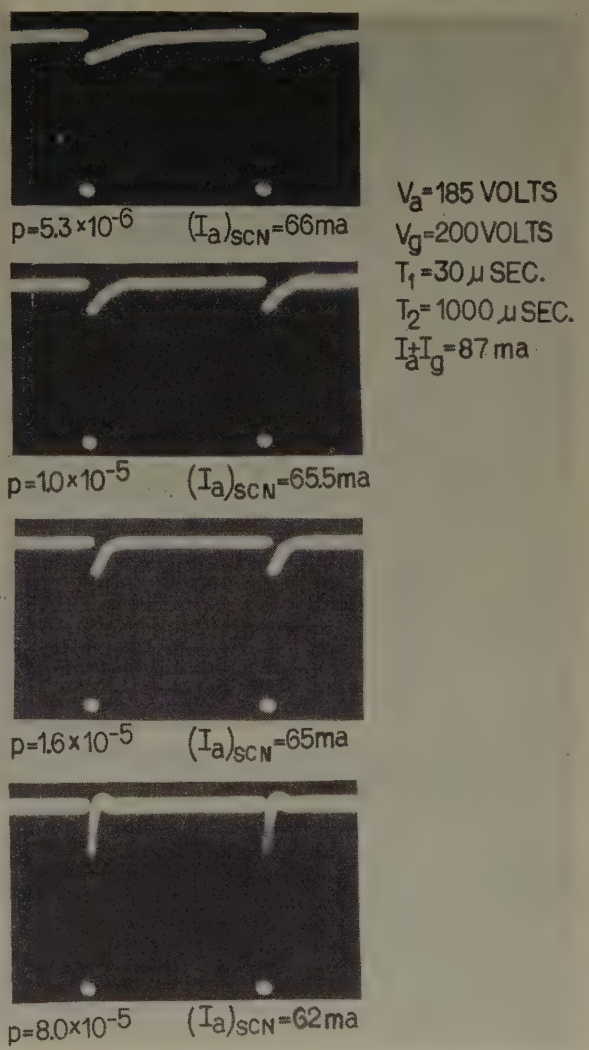

Fig. 12—Oscillograms of the screen-grid current showing the effect of pressure variation (p in mm of mercury).

Acknowledgment

The author wishes to thank Herbert Steyskal for helpful discussions during progress of this work.

[9] I. Langmuir and K. T. Compton, "Electrical discharges in gases," *Rev. Mod. Phys.*, vol. 2, p. 239; 1930.
[10] J. R. Pierce, "Possible fluctuations in electron streams due to ions," *Jour. Appl. Phys.*, vol. 19, pp. 231–236; March, 1948.

Space-Charge Effects in Reflex Klystrons*

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Summary—**Space charge in reflex tubes has an effect which causes considerable departure from the existing reflex theory. To a first order, it modifies the electronic admittance by a bunching effectiveness parameter, designated F, which, in general, takes some value between one and three.**

Several approximate methods have been used to estimate this F factor and the results are presented graphically for comparison with experimental measurements on the 723A/B reflex tube, showing good first-order agreement.

I. Introduction

THE SIMPLE THEORY of the reflex klystron has been given by various authors.[1–4] Although the form of the theory differs somewhat among the various presentations, essentially they all give the same result. One useful form of the theory represents the effect of the electron beam as an equivalent admittance across the resonator gap. This is called the "electronic admittance." It is a nonlinear function of the radio-frequency voltage across the gap, and a steady state of oscillation occurs when the radio-frequency voltage and frequency are such that the electronic admittance is the negative of the passive resonator admittance. This electronic admittance depends on the detailed trajectories of the electrons in the reflector region, and, in the conventional treatment, it has been assumed that the field in the reflector region is constant as between plane-parallel electrodes. This neglects the effects of finite reflector size, reflector curvature, and space charge. In this paper some calculations and measurements are discussed which deal with the space-charge effects and which lead to some semiquantitative values for the magnitude of these effects. In the calculations, the approximation of plane-parallel electrodes in the reflector region is retained, but, in comparing with the experimental results, a correction is made for curvature of the reflector. Neglecting the finite cross section of the electron beam should not be too serious if the beam diameter is large compared to the reflector spacing. This condition holds for many existing reflex tubes.

The electronic admittance in general is defined as the ratio of the effective radio-frequency current in the beam to the radio-frequency gap voltage. In the simple theory assuming constant reflector field this turns out to have the magnitude

$$|Y_e| = 2\mu \frac{I_0 J_1(X)}{V_1} \tag{1}$$

where X is the bunching parameter defined as

$$X = \pi N \frac{\mu V_1}{V_0}. \tag{2}$$

I_0 and V_0 are beam current and beam voltage; V_1 is radio-frequency gap voltage; N is the number of cycles transit time in the reflector region; μ is the beam modulation coefficient; and J_1 is the first-order Bessel function. It is assumed here that all the bunching takes place in the reflector region so that N represents the total transit time between successive passages through the gap. If there is any field-free drift region preceding the reflector region, such as a grid of finite thickness, N must be replaced by the difference between reflector transit angle and field-free transit angle.

Although the admittance as defined in (1) is customarily used in discussing reflex tubes, it is possible to derive a more general equation for the electronic admittance which at least formally contains the effect of a nonconstant field.[5] In this more general case, the argument X of the Bessel function is replaced by FX, where

$$F = \left(\frac{2V_0}{\theta}\right)\frac{d\theta}{dV}$$

($\theta = 2\pi N$ is transit angle in radians) can be called the "drift effectiveness factor." As defined, F represents the effect of nonconstant fields only for small radio-frequency voltages, but it is probable that for usual operating conditions in practical tubes it does remain a valid concept. Although a formal definition of F is possible, a quantitative evaluation for any specific geometrical configuration of the reflector or set of space-charge conditions is not simple.

In succeeding sections some approximate methods of calculating the F factor due to space charge are described, and also some measurements on existing reflex tubes. Although the calculations are necessarily crude

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[1] J. R. Pierce and W. G. Shepherd, "Reflex-oscillators," *Bell Sys. Tech. Jour.*, vol. 26, pp. 460–681; July, 1947. See page 481.

[2] E. L. Ginzton and A. E. Harrison, "Reflex-klystron oscillators," PROC. I.R.E., vol. 34, pp. 97–113; March, 1946.

[3] J. C. Slater, "Microwave Electronics," D. Van Nostrand Co., Inc., New York, N. Y.; 1950.

[4] D. R. Hamilton, J. K. Knipp, and J. B. H. Kuper, "Klystrons and Microwave Triodes," McGraw-Hill Book Co. Inc., New York, N. Y.; 1948.

[5] A. H. W. Beck, "Velocity-Modulated Thermionic Tubes," The Macmillan Co., New York, N. Y., p. 120; 1948. Beck uses R, where $R = F/2$.

because of the inherent multistream character of the electron flow in the reflector region, the agreement among the various methods of calculation and the measurements is quite good. The value of F is found to range between one and three for operating conditions quite typical of those for existing tubes. These large F values indicate that space charge quite drastically modifies the behavior of reflex tubes and must be considered seriously in the design and performance analysis of such tubes.

II. The Static Solution

Before considering the problem of velocity-modulated electrons in the reflector region, it is useful to consider the trajectories, field distribution, and transit time for the static case, i.e., with no modulation.

Neglecting space charge, the field in the reflector region is constant and the time trajectories are simple parabolas as shown in Fig. 1. When space charge is present the trajectories have the same general shape, but space-charge components must be added to the field and potential in the reflector region. The resultant field and potential are shown in the same figure. It may be noted that the derivative of the field has a singularity at the turn-around plane for the electrons.

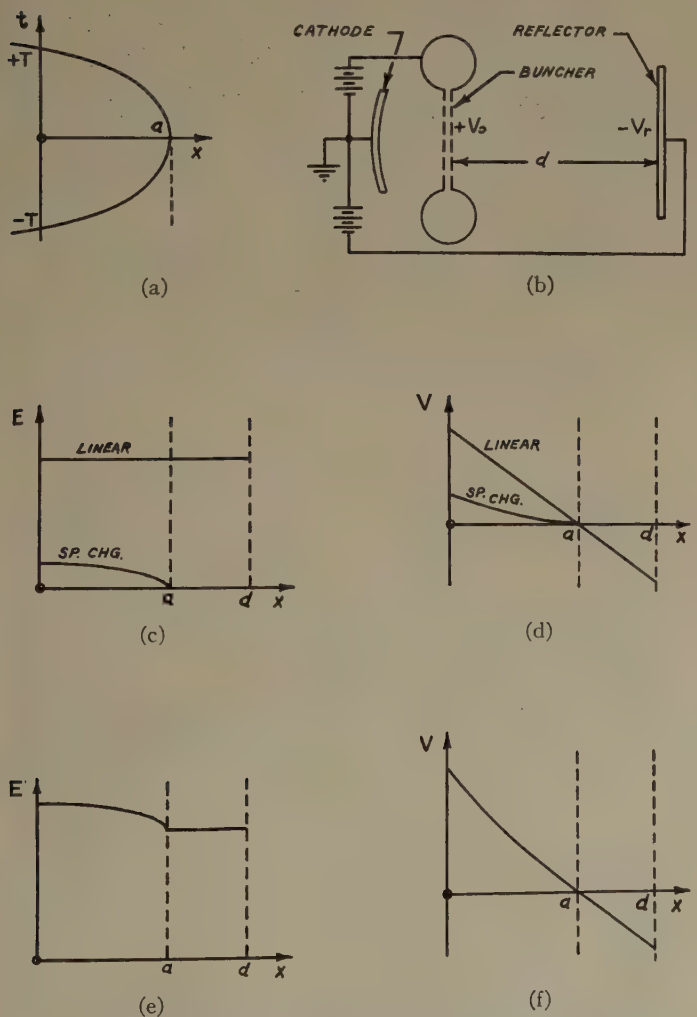

Fig. 1—Field and potential as a function of distance in the reflector region. (a) Electron trajectory. (b) Reflex tube. (c) Linear and space-charge components of field. (d) Linear and space-charge components of potential. (e) Resultant field in reflector region. (f) Resultant potential in reflector region.

For the derivation of the trajectories, considering space charge, one has Gauss' law and the current identity

$$\partial E'/\partial x = \rho/K \tag{3}$$

and

$$\rho = -2Jdt/dx \tag{4}$$

where E' is the field, ρ is the charge density, J is the current density, and K is the permittivity of free space. The factor 2 must be added to take account of the current due to both entering and returning electrons.

What is needed to solve the equation of motion is the field E', as seen by the moving electron. One can write for the *total* derivative of the field, i.e., the rate of change as seen by the moving electron,

$$dE'/dt = \partial E'/\partial t + (dx/dt)(\partial E'/\partial x)$$

but since $\partial E'/\partial t = 0$, one has simply

$$\partial E'/\partial x = (dE'/dt)(dt/dx).$$

Substituting this relation in (3) together with the expression for ρ, one obtains

$$dE'/dt = -2J/K$$

which upon integration becomes

$$E' = -2Jt/K + C. \tag{5}$$

Each electron being subject to this field, the equation of motion is simply

$$\ddot{x} = -eE'/m. \tag{6}$$

For this static case, even though the velocity at each point is double-valued, a simple solution is possible because of the symmetric nature of the trajectories, such that electrons traveling in opposite directions have velocities of equal absolute magnitude.

The acceleration of the electron, from (5) and (6), becomes

$$\ddot{x} = -(e/m)(-2Jt/K + C). \tag{7}$$

This is one form of Llewellyn's basic relation,[6] used to treat similar space-charge problems.

Integrating twice and evaluating the constants in terms of the boundary conditions, namely, the field $V_r/(d-a)$ at the distance of greatest penetration of the electrons a, (7) becomes

$$x = -(e/m)[-Jt^3/3K + V_r t^2/2(d-a)] + a. \tag{8}$$

[6] F. B. Llewellyn, "Electron-Inertia Effects," Cambridge University Press, London; 1941.

In terms of the initial velocity v, another boundary condition is utilized, yielding the second of the two equations which may be solved simultaneously for the half-transit time T,

$$v = (e/m)[JT^2/K + V_rT/(d-a)] \tag{9}$$

where

$$v = \sqrt{2eV_0/m}.$$

Rewriting (8) for the corresponding conditions, which are $x=0$ and $t=-T$

$$0 = -(e/m)[JT^3/3K + V_rT^2/2(d-a)] + a. \tag{10}$$

In order to proceed with the simultaneous solution it is desirable to reduce the number of variables in (9) and (10). By application of dimensional analysis[7] it may be shown that the half-transit time, when properly normalized, is expressible as a function of just two parameters, a normalized current density and reflector voltage. Normalized quantities will be underlined hereafter and are defined as follows:

$$\underline{V} = V_r/V_0 \qquad \underline{J} = Jd^2/V_0vK$$
$$\underline{x} = x/d \qquad \underline{a} = a/d$$
$$\underline{t} = tv/d \qquad \underline{T} = Tv/d$$
$$\underline{E} = Ed/V_0, \quad = \underline{V}/(1-\underline{a}) \qquad \underline{\dot{x}} = \dot{x}/v.$$

Here, for convenience, we summarize the notation previously introduced. V_r and V_0 are the reflector and accelerating voltages. v is the entering velocity, x is the displacement, and a is the penetration distance of an electron. t is the time corresponding to the displacement x, and T is half the transit time. d is the distance between the entrance plane and the reflector electrode and E is the field at the turn-around plane, i.e., $V_r/(d-a)$. K is the permittivity of free space.

Using these normalized parameters, (9) and (10) assume in the dimensionless form

$$\underline{J}\underline{T}^2/2 + \underline{V}\underline{T}/2(1-\underline{a}) - 1 = 0 \tag{11}$$

$$\underline{J}\underline{T}^3/3 + \underline{V}\underline{T}^2/2(1-a) - 2\underline{a} = 0. \tag{12}$$

The solution of these equations for the half-transit time $\underline{T}$ is given in graphical form in Fig. 2.

One of the tacit assumptions has been that the electrons at any plane have the same absolute velocity; in other words, the thermal spread of velocities has been neglected. This assumption is justified for the magnitude of accelerating voltage which is used in klystron work, and the more general development of Fay, Samuel, and Shockley[8] has proceeded on the same basis. In their work, the aim has been to find the potential as a function of distance and the results are less suited for the purpose at hand. In this paper, the electron trajectory itself is of greater interest and it becomes possible to express both the potential, as seen by the electron, and distance as rather simple explicit functions of time. In normalized form these functions are

$$\underline{x} = \underline{J}\underline{t}^3/6 - \underline{V}\underline{t}^2/4(1-\underline{a}) + \underline{a} \tag{13}$$

and

$$\underline{V}' = \underline{\dot{x}}^2 = [\underline{J}\underline{t}^2/2 - \underline{V}\underline{t}/2(1-\underline{a})].^2 \tag{14}$$

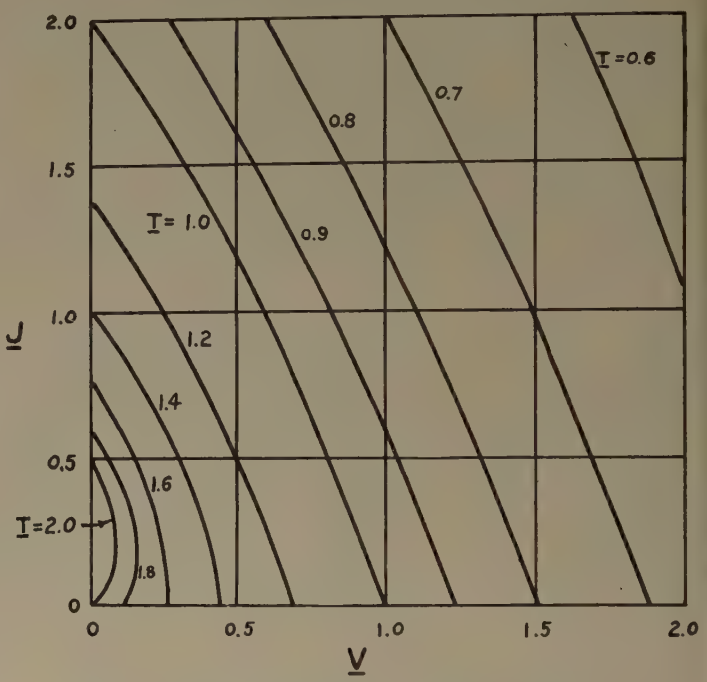

Fig. 2—The static solution for the half-transit time.

III. General Analysis for Nonstatic Case

In order to evaluate the F factor exactly, it is necessary to deal with time-varying fields in the reflector region. This is the result of the fluctuating nature of the space charge in the reflector region under conditions of modulation and the fact that the electron transit time is of the order of several cycles.

There is no general and exact analysis for the fields and trajectories under conditions where the various electrons at a given point and time may have several different velocities, positive and negative. The problem is made difficult because the electron trajectories depend on the fields directly through Newton's second law, while the fields in turn are determined by the charge distribution (and hence the trajectories) through Gauss' law.

The general solution to the problem can be expressed in the form of two equations for the geometry and boundary conditions which have been set forth. To do this, it is necessary to recall that the beam can have two or several components at a given point, corresponding

[7] V. Westburg, "The Electronic Admittance of the Reflex Klystron in the Presence of Space Charge," Ph.D. Thesis, Stanford University, Stanford, Calif.; 1949.

[8] C. E. Fay, A. L. Samuel, and W. Shockley, "On the theory of space charge between parallel plane electrodes," *Bell Sys. Tech. Jour.*, vol. 17, pp. 49–79; January, 1938.

to electrons traveling with different velocities. Associated with each component there is a component charge density and current density. Let these quantities for the nth component (or nth sheet, considering a contour surface of the functions plotted over the $x-t$ plane) be designated J_n and ρ_n, such that

$$\rho(x, t) = \sum_n \rho_n(x, t) \quad \text{and} \quad J(x, t) = \sum_n J_n(x, t).$$

In terms of these quantities the first equation, based on Newton's law and Gauss' law, is

$$\partial(J_n/\rho_n)/\partial t + (J_n/\rho_n)\partial(J_n/\rho_n)/\partial x = (e/m)\left\{(V_0 + V_r)/d + (1/Kd)\int_0^d \left[\int_x^d \rho(X, t)dX\right]dx - (1/K)\int_x^d \rho(X, t)dX\right\}. \quad (15)$$

The second equation, the charge conservation principle, is

$$\partial J_n/\partial x + \partial\rho_n/\partial t = 0. \quad (16)$$

The solution of (15) and (16) simultaneously for $J(x, t)$ and $\rho(x, t)$ as n-sheeted functions in the $x-t$ plane constitutes the general solution of this space-charge problem.

Not only is it difficult to carry out the exact solution for the trajectories, but many obvious approximate solutions for the F factor also fail.

Two methods of approximation have been used by Sollfrey.[4,9] Although these have certain limitations for vanishing signals, it is possible to compute the F factor for assumed values of Δ, the modulation coefficient, defined in Section V. His results are tabulated below:

$\underline{JT}^2\backslash\Delta$	0.025	0.05	0.10
0.34		1.38	
0.70	3.12	2.54	1.70
1.07	4.06	2.76	

Several such approximate methods, including the one of the following section, ignore the fact that the F factor is a function of the transit time relative to the modulation period. This is probably a serious omission, however, since the time variation of the fields near the turn-around plane is great and the electrons pass through this region slowly.

A method of field perturbation, discussed in detail in Section V, is an attempt to include this factor. The method gives a certain insight into the way in which transit-time variations take place from point to point in the orbit, and, of various approximate methods, it provides the best agreement with experimental results.

[9] W. Sollfrey, "Space Charge Effects in Reflex Klystrons," Sperry Gyroscope Co., Great Neck, L. I., N. Y., Report No. 5221–1084, p. 3.

IV. The F Factor from the Static Solution

The exact static solution of Section II may be extended to cover the case where the entering velocity of the electrons is modified by an incremental amount of velocity modulation. The F factor is proportional to the first derivative of transit time with respect to the entering velocity, subject to the restriction that the fields in the reflector region are sensibly constant during the time of transit of an electron, corresponding to modulation at a very low frequency.

To find the first derivative, the variable $\underline{a}$ is eliminated between (11) and (12), at the same time including the entering velocity $\underline{v}$ (although it has a normalized value of unity when there is no modulation)

$$-\frac{\underline{J^2T^5}}{6} + \frac{4\underline{JT^3v}}{3} - 2\underline{JT}^2 - 2\underline{VT} - 2\underline{v}^2\underline{T} + 4\underline{v} = 0.$$

The variable $\underline{V}$ appears in this equation, but it is expressible as

$$\underline{V} = (1 + V_r/V_0) - \underline{v}^2$$

since the square of the entering velocity represents the difference in potential between the entrance and turn-around planes.

Differentiating with respect to $\underline{v}$ and simplifying, the F factor is found to be

$$F = \frac{1}{\underline{T}}\left(\frac{d\underline{T}}{d\underline{v}}\right) = \frac{2\underline{JT}^3 + 6}{\underline{J^2T^5} - 4\underline{JT}^3 + 3\underline{JT}^2 + 6}. \quad (17)$$

When $\underline{J}=0$, the charge-free case, this expression reduces to unity properly enough.

A plot of the F factor from the static solution is given in Fig. 3.

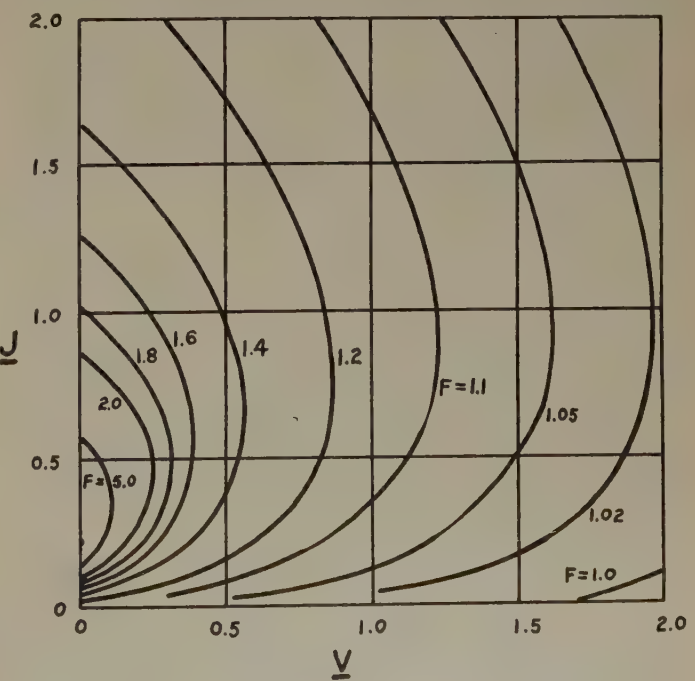

Fig. 3—The F factor from the static solution.

The restriction on the validity of the F factor from this method is simply that $T \ll T_0$, where T is the half-transit time and T_0 is the modulation period. In other words, this F factor is only valid when the time variations are very slow.

V. The F Factor by a Method of Field Perturbation

An approximate value for the F factor can be derived by a method in which one makes use of a time-dependent perturbation of the field in the reflector region. In this method, assuming that the electron trajectory, to a first approximation, remains unchanged from the space-charge-free case, one calculates the effect of a time-varying field on the electron motion. This is entirely analogous to the method of calculating gap transit effects in triodes and klystrons, where one calculates the effect of the gap field on the motion of the electron, assuming the electron has a velocity corresponding to the dc potential.[4,6]

Otherwise stated, one computes the trajectories of velocity-modulated electrons in a constant (space-charge-free) field. From these, a time-dependent space-charge contribution to the field is calculated and then the effect of this extra field as a perturbation is determined, using the original trajectory and the modified field in the transit time integral

$$T = 2\int_{v_1}^{v_2} [1/\underline{E}'(\dot{x})]\, d\dot{x} \qquad (18)$$

where $\underline{v}_2$ and $\underline{v}_1$ are the entering and leaving velocities, respectively.

$\underline{T}$ from (18) does not correspond to the transit time of an electron free to move at will after being introduced into the field $\underline{E}'(x, t)$, but rather it is an integration along a certain "synthetic trajectory." The property of this synthetic trajectory is that an electron "sees" a time-modulated field in this hypothetical orbit similar to that experienced by an electron in the true orbit. This perturbing field $\underline{E}'(x, t)$ has the desirable property of approaching the actual time-varying field which exists in the reflector region in the limit of no space charge. The accuracy of the results will depend on how much the perturbing field affects the original unperturbed trajectory. As applied here, the accuracy of the method is undoubtedly less than in the original applications by Llewellyn *et al.*[6] Nevertheless, the displacement of an electron with time is the second integral of the field determining its motion; hence, relatively large field fluctuations, and corresponding accelerations, are not reflected by large changes in the trajectory.

To determine $\underline{E}'(\underline{x}, \underline{t})$ it is first necessary to know the charge distribution assuming the parabolic trajectories of the Webster theory for a given modulation level. While an analytic treatment is possible, the Appelgate diagram on $\underline{x}-\underline{t}$ co-ordinates affords an expedient way of determining the charge distribution. From such a diagram, the field $\underline{E}'$ can be determined at any point $(\underline{x}, \underline{t})$ as the sum of the original constant field plus a time-dependent space-charge contribution. The velocity of a given electron at a point $(\underline{x}, \underline{t})$ on its trajectory is easily found from the Webster theory, and with the knowledge of $\underline{E}'$ and $\dot{\underline{x}}$ at all points on a given trajectory the transit time can be computed from (18).

Fig. 4 shows the variation of $\underline{E}'$ versus $\dot{\underline{x}}$ along the trajectory for the electrons with the greatest and least entering velocities on $\underline{E}'-\dot{\underline{x}}$ co-ordinates. The curve for a given electron when $\Delta = 0$ is also shown. Δ, the modulation coefficient, is defined as $\underline{v}_2 = (1+\Delta)\underline{v}$, where $\underline{v}_2$ and $\underline{v}$ are the entering and unmodulated velocities of the electron, respectively. The area on these co-ordinates has the dimensions of transit time; hence the F factor is simply the difference in area between the curves for the fast and slow electrons, divided by the difference in entering velocity 2Δ.

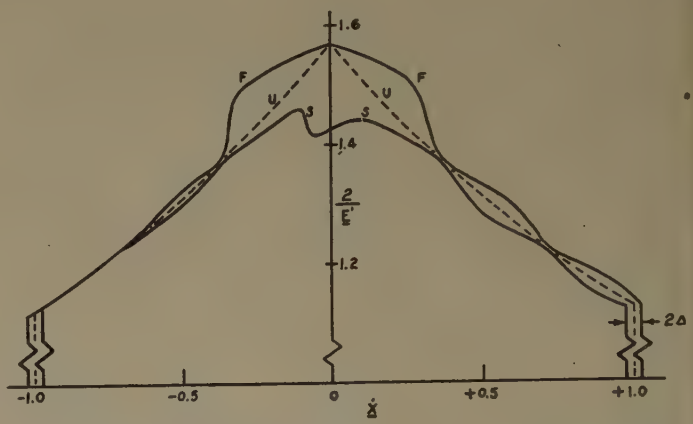

Fig. 4—Graphical integration for transit time by the method of field perturbation for a typical case.

$J = 0.22$
$\overline{V} = 0.5$
$J\overline{T}^2 = 0.37$
$\overline{N} = 2.77$
$\Delta = 0.025$
$N^2\Delta = 0.2$
F = fast electron
S = slow electron
U = unmodulated electron.

Curves for the fast and slow electrons in Fig. 4 give a clear conception of the manner in which the electron experiences field variations at the signal frequency during its transit through the reflector region. In particular, much of the difference in transit time is seen to accrue near the turn-around plane $\dot{\underline{x}} = 0$, and the curves are by no means symmetrical about this ordinate.

Fig. 5 gives the values of the F factor for various degrees of modulation and transit time in cycles. The abscissa $J\underline{T}^2$ is a single parameter which includes the effects of both $\underline{J}$ and $\underline{V}$ and which defines a certain relative static field shape in the reflector region. The use of this parameter as a simplification appeared possible in applying the method of field perturbation, and as an approximation seemed to be adequately justified.

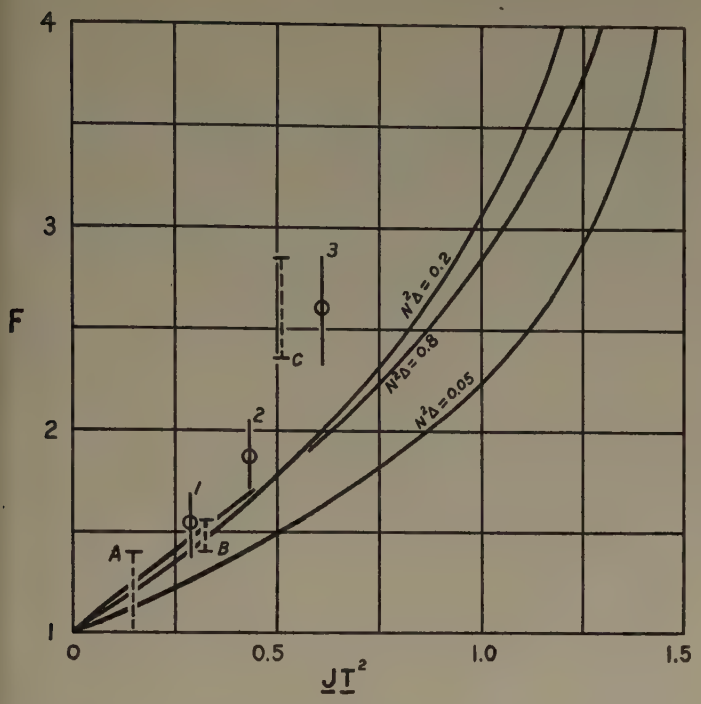

Fig. 5—The F factor from the method of field perturbation and measured values.

Measurement	Tube	N	$N^2\Delta$	$\underline{J}T^2$	F
1	723A/B	4.25	0.523	0.29	1.54
2	723A/B	5.25	0.560	0.44	1.87
3	723A/B	6.25	0.505	0.61	2.59
A	SRC-2	2.43	0.63	0.15	1.07
B	SRC-2	3.43	0.78	0.33	1.47
C	SRC-2	4.43	0.59	0.53	2.61

The curves in Fig. 5 are labeled with respective values of $N^2\Delta$. It may be shown from the parabolic shape of the trajectories that for constant values of the parameter $N^2\Delta$ the family of trajectories on the Appelgate diagram has very nearly the same appearance near the turn-around plane.[7] Thus the parameter $N^2\Delta$ may be thought of as defining the relative positions of the trajectories on the Appelgate diagram near the turn-around plane. Since it seems reasonable to suppose that the F factor is determined by this factor, computations were made for two different transit-time modes having the same value of $N^2\Delta$ and such indeed was found to be the case. The curves of Fig. 5 were computed for the following three values of the parameter $N^2\Delta$,

$$N^2\Delta = 0.05 \quad \Delta = 0.025 \quad N = 1.385$$
$$N^2\Delta = 0.20 \quad \Delta = 0.025 \quad N = 2.77$$
$$N^2\Delta = 0.80 \quad \Delta = 0.10 \quad N = 2.77$$

By way of examination, the method of field perturbation may be used to compute the F factor for a case in which the exact value is known. Such a case, corresponding to the conditions of validity for the F factor from the static solution, is when the electron transit time is a small fraction of a modulation period. For representative parameters, $\underline{J}=2/9$ and $\underline{V}=1/2$; these values of the F factor are 1.25 by the method of field perturbation and 1.29 from the static solution.

VI. Experimental Determination of the F Factor

It is possible, by a suitable combination of measurements and use of the theory of a reflex oscillator, to determine approximately the F factor of a reflex tube operating in any mode. These measurements were made on several tubes and the results are in good agreement with the theoretical calculations. To describe this method, a number of relations are required from the theory of a reflex oscillator. These have been derived elsewhere[1–4,10] and are listed here without proof.

First, the electronic admittance at the center of a mode can be written as

$$Y_e = -\mu^2 \frac{\theta F I_0}{V_0} \frac{J_1(FX)}{FX} = -2G_e \frac{J_1(FX)}{FX} \tag{19}$$

where G_e, as defined here, is known as the small signal electronic conductance. μ, the beam modulation coefficient, is defined as

$$\mu = \frac{\sin \phi/2}{\phi/2} \tag{20}$$

where ϕ is the transit angle between the grids. The condition determining the steady-state oscillation is that the electronic admittance be the negative of the circuit admittance. At the center of the mode, the admittances are pure conductances and the condition for oscillation can be written as

$$2G_e \frac{J_1(FX)}{FX} = \omega C\left(\frac{1}{Q_0'} + \frac{G}{Q_e}\right). \tag{21}$$

The cavity admittance on the right consists of two parts—the first due to the internal losses (i.e., cavity plus beam loading losses), and the second due to the external load, coupled to the cavity by means of some transmission line. Thus, in terms of the loaded Q, Q_L, given by

$$\frac{1}{Q_L} = \frac{1}{Q_0'} + \frac{G}{Q_e},$$

$1/Q_0'$ represents the internal losses and G/Q_e the load losses. Here G is the external load conductance normalized to the characteristic admittance of the transmission line and measured at a suitable plane in the line. Q_e is a factor representing the coupling between cavity and line and is more precisely defined below where the method of measuring is discussed. ωC is a geometric factor equal to the ratio of cavity Q to cavity impedance. The power output is equal to the product of load conductance as seen at the gap, by the mean-square voltage, i.e.,

[10] M. Chodorow, "Theory of Reflex Oscillators," part 1, Sperry Gyroscope Co., Great Neck, L.I., N.Y., Report No. 5221–1079; 1947.

$$P = V_1^2 \frac{\omega CG}{2Q_e} = \frac{V_1^2}{2}\left[2G_e \frac{J_1(FX)}{FX} - \frac{\omega C}{Q_0'}\right] \quad (22)$$

which can be written as

$$P = \frac{P_0}{F\theta}\left[2(FX)J_1(FX) - \frac{(FX)^2\omega C}{G_e Q_0'}\right] \quad (23)$$

where $P_0 = I_0 V_0$.

To find maximum power possible in a given mode, one differentiates with respect to the bunching parameter FX, and setting the derivative equal to zero, obtains

$$J_0(FX) = \frac{\omega C}{G_e Q_0'} \quad (24)$$

as the condition determining FX for optimum power. By means of a recurrence formula for the Bessel functions and (21), one obtains a related equation for the optimum load

$$J_2(FX) = \frac{\omega CG}{G_e Q_e}. \quad (25)$$

Simply stated, if one adjusts the load for optimum power, then (24) and (25) are simultaneously satisfied or, taking their ratio,

$$\frac{J_2(FX)}{J_0(FX)} = \frac{GQ_0'}{Q_e}. \quad (26)$$

One more equation is required, that for the electrical tuning, i.e., rate of frequency change with reflector voltage. This can be written as

$$\frac{\Delta f}{\Delta V_r} = -\frac{f_0}{2}\left(\frac{\Delta\theta}{\Delta V_r}\right)\left(\frac{1}{Q_0'} + \frac{G}{Q_e}\right) \quad (27)$$

where f_0 is the resonant frequency of the cavity and $\Delta\theta/\Delta V_r$ is the rate change of transit angle with reflector voltage. Equation (27) is valid for changes in θ such that $\tan(\Delta\theta) = \Delta\theta$.

Using these formulas then, in particular (22), (26), and (27), and some measured quantities, one can determine the F factor. By measuring G the optimum load, Q_e, and Q_0' one can get FX for optimum power from (26); from the optimum power and ωC one gets V_1 from (22). By determining μ and θ and using these values of FX and V_1, F is given by

$$F = \frac{2V_0(FX)}{V_1\mu\theta}. \quad (28)$$

The various measurements involved will be briefly described; most of them are described in greater detail in the literature. To determine θ, a mode plot of reflector voltage versus accelerating voltage for constant frequency of oscillation can be made. In particular, it can be shown from dimensional analysis that for constant ratio of V_r/V_0, $\theta\sqrt{V_0}$ will be constant. By finding a number of modes it is possible to assign values of θ unambiguously.

μ (20) can be found from the gap spacing and the acceleration voltage. Q_e is obtained by a cold measurement. Q_e represents the coupling between the tube resonator and the transmission line which couples the external load to the tube. It can be shown that the input admittance Y, looking into the cavity from a particular plane in the transmission line, is given by

$$\frac{Y}{Y_0} = \frac{Q_e}{Q_0}(1 + 2j\delta Q_0) \quad (29)$$

where Y_0 is the characteristic admittance of the transmission line, δ is the fractional deviation from the resonant frequency of the cavity, and Q_0 is the cold Q of the cavity. The particular plane for which (29) applies is that at which there is a voltage minimum in the line if a measurement is made at the resonant frequency of the cavity with the cavity detuned. This plane is called the "detuned short." By measuring Y as a function of frequency, Q_e can be determined. The value of G, the normalized load conductance for optimum power, which appears in (26), is also to be measured at the same "detuned short" plane. Q_0 in (29) is *not* identical with Q_0' in general since it contains no beam loading effects. To find Q_0' it is necessary to measure the modulation sensitivity, $\Delta f/\Delta V_r$. By use of (27) it is possible to get Q_0'. This measurement is made with G having the value for optimum power. $d\theta/dV_r$ is found from the same mode plot measurements used in getting θ, and finally ωC is determined with sufficiently good accuracy assuming a field distribution in the cavity and calculating the conductance-Q ratio. It has been shown that this ratio, and indeed the separate factors in it, are quite insensitive to the assumed field.[11]

VII. Discussion of Experimental Results and Conclusions

The experimentally determined values of the F factor for the 4.75, 5.75, and 6.75 modes in the 723A/B tube operating at a wavelength of 3.2 cm are plotted in Fig. 5. Each of these points represents the average of the values in a given mode for the three tubes used in the measurements. The vertical bar through each of these points indicates the 95-per cent confidence limits on the measurements. The vertical dashed bars represent the spread of measurements on a quite different reflex tube—the SRC-2 at a wavelength of 6 cm.

The experimental F factor, F, includes both the effects of space charge and of the nonconstant reflector field because of the reflector geometry itself. Since the latter effect is not appreciable, it was assumed that the two effects were independent and could be superimposed.

[11] M. Ettenberg, "Calculations of Q and Shunt Impedance of Reentrant Cavities," Sperry Gyroscope Co., Great Neck, L.I., N.Y., Report No. 5221–1076; January 3, 1947.

Measurements of the static transit time as a function of reflector voltage for the 723A/B tube indicate that the field in the reflector region is nearly that between two concentric spheres having a ratio of radii of 1.15. Curves calculated by Zitelli[12] for this case were used to find the F factor due to the nonconstant reflector field alone, of the order of 1.2 to 1.3.

A correction has also been applied to account for the field-free bunching which takes place between the resonator grids. The experimental F factor in the reflector region alone F_r may be computed from the expression

$$F_r = (F\theta + \phi)/(\theta - \phi)$$

where F is the measured F factor, θ is the total transit angle, and ϕ is the transit angle between resonator grids. With the inclusion of such corrections, the measured values in Fig. 5 express the effects of space charge alone in the reflector region.

It is likely that the difference between the experimental and theoretical values of the F factor is not experimental error but inherent in the approximation of the method of field perturbation itself. Notwithstanding, the first-order agreement between the measurements and theory is token in itself of the usefulness of the method of field perturbation.

The plotted points in Fig. 5 have required an estimate of the beam current density J. This was done by assuming a uniform current density across the entire grid aperture. Depending on the efficiency of focussing, however, the effective current density could be somewhat greater if the beam diameter were less than that of the aperture. This effect, if present, would reduce the difference between the experimental points and the theoretical curves.

Certain general observations can be made concerning the F factor, as seen from Figs. 2, 3, and 5. First, for constant J, the F factor increases monotonically with N. Second, for cases of general interest, the F factor in a given mode (for constant N) increases with J, the current density, or with the beam perveance for a constant reflector distance d. Thus, space charge in reflex tubes results in an F factor greater than unity, and the effect becomes increasingly more important as the current density is increased and as the reflector voltage is decreased.

The effects of this F factor on general reflex-tube behavior are the following: Essentially, the effective value of the bunching angle in the reflector region is no longer N, but FN, and in considering all the properties of a reflex tube depending on the bunching angle this distinction between the two must be considered. The only place in the reflex-tube theory where the true transit angle is relevant is in determining the phase of the bunched current. In all properties relating to amplitude, efficiency, power output, and so on, FN is the relevant parameter and must be used in calculating these quantities.

An important consequence of the space charge causing an F factor greater than unit relates to the design of low-frequency reflex tubes. From what has been said previously, it is apparent that, for a constant current density, as the transit time increases the F factor also increases. Quantitatively, if N is kept constant and the frequency varied, the parameter JT^2 varies as J/f^2, and F varies somewhat more rapidly than JT^2. Therefore, FN increases and the conversion efficiency and the power output eventually decrease to a negligible value as the frequency is lowered. This can be somewhat circumvented by going to smaller N; but there is a smallest value of N permitted, for phase reasons, i.e., 3/4 cycle, and beyond this no decrease is possible by simple means.

An interesting consequence concerning the maximum conversion efficiency in a given mode, i.e., the power delivered to the cavity plus load divided by the dc input power, is indicated by the calculation of F. Since F is greater than unity, FN is greater than N, and therefore the maximum conversion efficiency, being equal to $0.398/FN$, is always reduced by space charge. The maximum power in a given mode, however, is equal to the product of the power input and the maximum conversion efficiency for the mode

$$P = 0.398V_0I_0/FN. \tag{30}$$

By referring to Fig. 5 it is seen that the F factor is a function of the beam current I_0 in such a way that the ratio I_0/F first increases, reaches a maximum, and then decreases as the current density is increased. This means that, because of the effects of space charge, there is a certain optimum value of beam current (with given values of V_0 and N) for which maximum power can be obtained.

While the maximum efficiency is decreased by the presence of space charge, the zero-signal admittance is increased in direct proportion to the F factor, with the result that signal power can be obtained at a proportionately lower impedance level.

Acknowledgment

The authors are grateful to Karl Spangenberg for his helpful criticisms and comments on this work. They also wish to thank J. Sadler of Sperry Gyroscope Company for making the data on SRC-2 available to them.

[12] L. T. Zitelli, "Repeller Field Shape as a Factor in the Design of Broadband Reflex Klystron Oscillators," Contract N6-onr-251, Consolidated Task 7, Technical Report No. 3; May 25, 1948.

A Circuit for Generating Polynomials and Finding Their Zeros*

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Summary—**This paper describes an instrument for generating any polynomial and for finding the roots of any polynomial equation to any desired degree of accuracy.**

I. Introduction

THE PURPOSE of this paper is to describe a device for generating the polynomial

$$\sum_{m=0}^{n} a_m z^m = a_0 + a_1 z + a_2 z^2 + \cdots + a_n z^n = f(z) \quad (1)$$

and for solving the equation

$$\sum_{m=0}^{n} a_m z^m = 0, \quad (2)$$

where $z = x + jy$ and $a_m = b_m + jc_m$.

The basic problems in the synthesis of an instrument for generating polynomials are the analogical representation of its individual terms and the addition of these terms. Since z is complex in general, a representation of a complex number is necessary, while to obtain z^2, a representation of the product of two complex numbers must be found. Presuming this can be done, z^3 may be found as the product of z^2 and z, z^4 as z^3 multiplied by z, and so on for all the powers of z, while the multiplication of the various powers of z by their coefficients may be similarly represented. Finally, the terms of (1) must be added to obtain $f(z)$.

The usual shorthand notation used by the electrical engineer to represent the steady-state solutions of the integrodifferential equations describing an electrical network suggests that an electrical circuit might be the basis for representing the operations with complex numbers if sinusoidal steady-state currents and voltages exist in the network. Circuits for multiplying and for adding complex numbers are explained in section II.

It is pointed out here that these circuits are capable of analogically performing the required arithmetic operations only for $|x|$, $|y|$, $|b_m|$, and $|c_m| \leqq 1$; although these restrictions in no way cripple the usefulness of the instrument, for in solving (2) $|b_m|$ and $|c_m|$ may be made $\leqq 1$ by dividing (2) by the largest real or imaginary coefficient part. Furthermore, to find roots of (2) with real and/or imaginary part >1, z may be replaced by $1/w$ to get

$$a_0 w^n + a_1 w^{n-1} + \cdots + a_n = 0, \quad (3)$$

whose roots have parts $\leqq 1$ corresponding to those roots of (2) which have parts $\geqq 1$. Thus (3) satisfies the requirements of the solver and enables the solution of (2).

Presuming that the coefficients of (1) have parts $\leqq 1$, $f(z)$ is suited to the circuits later described for $|x|$ and $|y| \leqq 1$, while to find $f(z)$ for $|x|$ and/or $|y| > 1$, (1) may be divided by $|z|^n$, where $|z|^n > 1$, to get

$$\phi(z) = \frac{f(z)}{|z|^n} = \frac{a_0}{|z|^n} + \frac{a_1}{|z|^{n-1}}(z/|z|) + \frac{a_2}{|z|^{n-2}}(z/|z|)^2 + \cdots + a_n(z/|z|)^n, \quad (4)$$

or letting $z' = z/|z|$, $a_{m'} = a_m/|z|^{n-m}$,

$$\phi(z) = \sum_{m=0}^{n} a_{m'}(z')^m, \quad (5)$$

where the parts of z' have moduli $\leqq 1$. Thus $\phi(z)$ satisfies the conditions required by the instrument and can be generated by it, while $f(z)$ is found from $\phi(z)$ by simple multiplication. If the largest coefficient part is >1, $f(z)$ or $\phi(z)$ divided by this largest coefficient part can be generated by the instrument, and again $f(z)$ is found by simple multiplication.

It is also possible to "contract" the variable by letting $z = kz''$, $k > 1$, so that

$$f(kz'') = a_0 + (a_1 k)z'' + (a_2 k^2)z''^2 + \cdots + (a_n k^n)z''^n, \quad (6)$$

which satisfies the condition $|x''| \leqq 1$, $|y''| \leqq 1$, while division by the largest coefficient part, if it is greater than unity, enables the generation of $f(z)$.

The origin of the variable z may also be shifted to obtain various results; this is covered in section IV C.

II. Circuits for Performing the Basic Operations

It has been shown[1] that the input and output voltages of the feedback amplifier shown in block form in Fig. 1

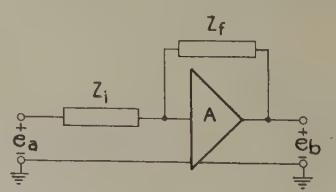

Fig. 1—A multiplying device.

* Decimal classification: 621.375.2. Original manuscript received by the Institute, August 22, 1950; revised manuscript received, March 5, 1951.

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[1] J. R. Ragazzini, R. H. Randall, and F. A. Russell, "Analysis of problems in dynamics by electronic circuits," PROC. I.R.E., vol. 35, pp. 444–452; May, 1947.

are related by

$$e_b = -(Z_f/Z_i)e_a, \tag{7}$$

provided the open-loop gain of the amplifier A is very large and the phase shift from the input to the output is approximately 180 degrees with the feedback loop open.

It has been shown also that the output voltage of Fig. 2 is related to the input voltages by

$$-e_t = (R_f/R_0)e_0 + (R_f/R_1)e_1 + \cdots + (R_f/R_n)e_n, \tag{8}$$

where the amplifier must meet the conditions above.

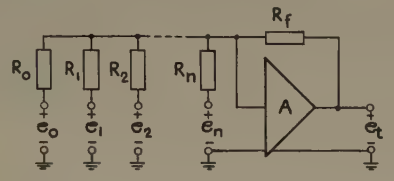

Fig. 2—Adding circuit.

It will now be shown that the input and output voltages of the circuit of Fig. 3 are related by

$$e_b = ze_a = (\pm|x| \pm j|y|)e_a, \tag{9}$$

where $|x|$ ($|y|$) is the fraction of the resistance of the potentiometer P_x (P_y) between brush and ground. It is assumed that the resistances R_3 are large enough so that

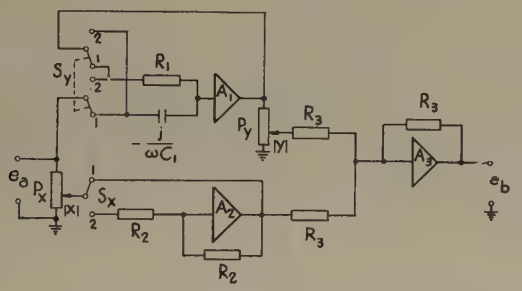

Fig. 3—A circuit for multiplying by any complex number.

they do not load the potentiometers P_x and P_y, and that the amplifiers A_1, A_2, and A_3 have large gain and approximately 180-degree phase shift with their feedback loops open. The components R_1 and C_1 are such that $R_1\omega C_1=1$, where ω is the angular frequency of e_a. The switch S_x is a single-pole double-throw type, while S_y is a double-pole double-throw switch.

Suppose S_x and S_y are both in the positions marked "1." By (7) the output voltage of A_1 is $e_1=-jR_1\omega C_1e_a = -je_a$, in view of the restrictions on the components. A portion of e_1, $|y|e_1$ is applied to the input of A_3 through a resistance R_3, while the voltage $|x|e_a$ at the brush of P_x is applied to the input of A_3 through another resistance R_3. By (8), the output voltage of A_3 is then

$$e_b = (-|x| + j|y|)e_a. \tag{10}$$

If S_x is in position 1, while S_y is in position 2, the feedback and input impedances of A_1 are interchanged. The output of A_1 is then $j|y|e_a/R_1\omega C_1=j|y|e_a$, so that the output voltage of A_3 is

$$e_b = (-|x| - j|y|)e_a. \tag{11}$$

As yet, no mention has been made of the purpose of switch S_x, which enables either the application of $|x|e_a$ directly to the input of A_3 through R_3, or the application of $|x|e_a$ to the input of A_2, and thence to R_3. The amplifier A_2 has equal input and feedback resistances (R_2): Its function is to change the sign of the voltage applied to its input. Thus, if S_x is in position 2, the output of A_3 is either

$$e_b = (|x| + j|y|)e_a \tag{12}$$

or

$$e_b = (|x| - j|y|)e_a, \tag{13}$$

depending upon the position of S_y.

Each of equations (10)–(13) is a special case of (9), hence the circuit of Fig. 3 will multiply its input voltage by any type of complex number whose parts have a magnitude of unity or less. This circuit is used to raise z to its various powers.

As a device for multiplying the various powers of z by their coefficients, the circuit of Fig. 4 is used. This

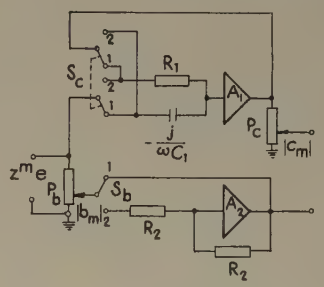

Fig. 4—A coefficient unit.

circuit is identical to part of Fig. 3; the amplifier A_3 and the resistances associated with it are omitted. Here $|b_m|$ is the fraction of the resistance of P_b between its brush and ground, while $|c_m|$ is the fraction of P_c between brush and ground. The input voltage to this unit is z^me, so that the voltage at the output of A_2, or at the brush of P_b depending upon the position of S_b, is $\pm|b_m|z^me$. The voltage at the brush of P_c is $\pm|c_m|z^me$, where, as in the unit of Fig. 3, $R_1\omega C_1=1$ and the signs are accounted for by the position of S_c.

III. A Circuit for Solving Polynomials with Complex Coefficients

The new circuit for solving polynomials is shown in block form in Fig. 5. Each of the cascaded blocks across the top of the diagram is meant to contain the circuit of Fig. 3; they are called "involution units" because they perform this operation upon the variable z. All of the P_x shafts are mechanically ganged so that the $|x|$'s in all units are the same. The P_y shafts are also ganged. To insure the same signs for the x's and y's in all units, the switches S_x are mechanically connected, as are the S_y's.

An alternating voltage e, of angular frequency ω, is applied to the first involution unit. By (9), the output voltage of this first unit is ze, and this voltage is applied to the input of the second involution unit so that its output voltage is z^2e, and so on. The outputs of the cascaded involution units are then successively ze, z^2e, z^3e, $\cdots$, z^ne.

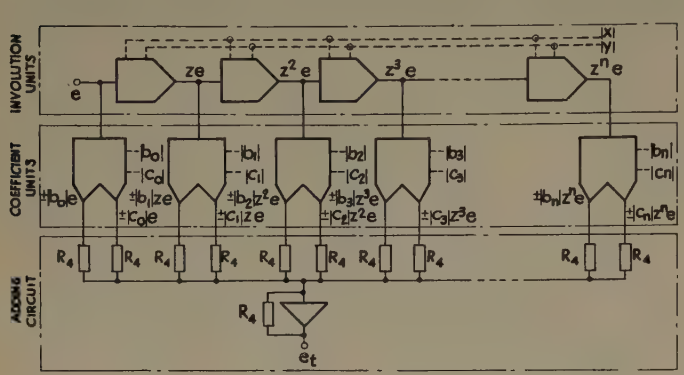

Fig. 5—Block diagram of an instrument for solving polynomials with complex coefficients.

Each of the coefficient units (the blocks connected to the output of each involution unit and going to the adding circuit) is the circuit of Fig. 4. The outputs of these latter blocks are evident from the voltages marked on the circuit. The adding circuit is the same as Fig. 2; the components marked R_4 are equal resistances.

By (8), the output voltage of the adding amplifier is

$$-e_t = (\pm|b_0| \pm j|c_0|)e + (\pm|b_1| \pm j|c_1|)ze + \cdots + (\pm|b_n| \pm j|c_n|)z^ne = \sum_{m=0}^{n} (\pm|b_m| \pm j|c_m|)z^me \quad (14)$$

or

$$-\frac{e_t}{e} = \sum_{m=0}^{n} (\pm|b_m| \pm j|c_m|)z^m = \sum_{m=0}^{n} (b_m + jc_m)z^m = \sum_{m=0}^{n} a_mz^m, \quad (15)$$

which is the polynomial (1), provided each $|b_m|$ and $|c_m|$ is properly adjusted (by adjusting the potentiometers P_b and P_c) and the switches S_b and S_c are appropriately set for each a_m.

Assuming the coefficients are properly set into the solver, $f(z)$ is found by comparing e_t to e for magnitude and phase. To change the variable, $|x|$ and $|y|$ are changed by adjusting the P_x potentiometers and the P_y potentiometers, while the positions of all of the S_x's and all of the S_y's determine the form of z. In order to generate $f(z)$ for $|x|$ and/or $|y|>1$, $\phi(z)$ or $f(kz'')$ mentioned in section I may be used. To generate $f(z)$ in the vicinity of a given z, the origin may be shifted to this value of z as shown in section IV C; this enables the accurate determination of $f(z)$ in a given vicinity.

To find a root of the polynomial equation, $|x|$ and $|y|$ are independently varied[2] until $e_t=0$; the values of $|x|$ and $|y|$ resulting in $e_t=0$ and the positions of S_x and S_y determine the root. This process is repeated until all roots whose parts are less than unity are found, when (3) is set into the instrument enabling the location of all roots with $|x|$ and/or $|y|>1$. By the successive approximation process shown in section IV C, a root may be found to any desired degree of accuracy.

IV. Operating Notes

A. An Example of the Preparation of a Polynomial for the Instrument

First, consider the solution of polynomial equations, and as an example, use the equation

$$400{,}000 + 24{,}000z + 220z^2 + z^3 = 0. \quad (16)$$

Although a cubic is used as the example, it should be remembered that the instrument is for solving polynomials that do not have literal solutions. It is also pointed out here that most of the calculations are of slide-rule accuracy only.

To set (16) into the instrument, first divide the equation by 400,000, the largest coefficient. This gives

$$1 + 0.06z + 0.00055z^2 + 0.0000025z^3 = 0. \quad (17)$$

Now it would be difficult to set the number 0.00055 into the solver with any degree of accuracy, even using a vernier attached to the P_b potentiometer, and it would be virtually impossible to set in the number 0.0000025. It appears that this polynomial must be "prepared" for the instrument.

Let $z=20z'$. Inserting this in (17), gives

$$1 + 1.2z' + 0.22z'^2 + 0.02z'^3 = 0 \quad (18)$$

or

$$0.8333 + z' + 0.1833z'^2 + 0.0167z'^3 = 0. \quad (19)$$

The coefficients of (19) could be set into the solver with much more accuracy than those of (17). Thus, by "contracting" the variable so that the new variable is $z'=z/20$, the "contracted" polynomial may be set into the instrument with a higher degree of accuracy.

It is also possible to shift the origin of z so that the coefficients are more nearly equal.

B. The Root-Finding Process

To show that a change in $|x|$ or $|y|$ resulting in a decrease in e_t is a step toward finding a root, write the polynomial as

$$f(z) = a_n(z-z_1)(z-z_2)(z-z_3)\cdots(z-z_n) = -e_t/e, \quad (20)$$

where $z_m (m=1, 2, 3, \cdots, n)$ are the zeros of (20).

[2] It is shown in section IV B that an adjustment of either $|x|$ or $|y|$, resulting in a decrease of e_t is a step toward finding a root.

Suppose that the polynomial has a zero $z_1=x_1+jy_1$ as shown in Fig. 6.

If the solver is originally set to $z_a=x_a+jy_a$, then $f(z_a)$ will have some value not zero. Suppose x is varied, while $y=y_a$ is not changed. As x is increased, $|f(z)|$ will tend to decrease because $|z-z_1|$ decreases. However, the minimum value of $|f(z)|$ may not occur at $z_c=x_1+jy_a$, although $|z_c-z_1|=y_1-y_a$ is certainly the smallest absolute value of the factor $z-z_1$, if only x is varied. It is probable that some value of $x=x_b$, other than x_1, will result in a minimum $|f(z)|$ because the product of the factors $|z_c-z_m|$ is enough larger than the product of the factors $|z_b-z_m|$, $m=2, 3, 4, \cdots, n$, so that $|f(z_b)|<|f(z_c)|$. Thus, if only x is varied until the magnitude of e_t reaches a minimum, then the value of $x=x_b$ will be near x_1, the real part of the root z_1.

Now suppose that only y is varied, while $x=x_b$ is not changed. When $|f(z)|$ reaches its minimum value, the value of z may be some value such as $z_d=x_b+jy_d$, where $y_d\neq y_1$. At this time x only may be varied again, then y, and so on. It is evident that each variation of x or y which reduces $|f(z)|$ (or e_t) will result in values of x and y closer to x_1 and y_1, respectively. When $|f(z)|=0$, then $z=z_1=x_1+jy_1$ and a root has been found.

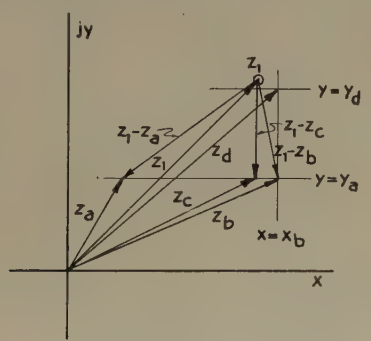

Fig. 6—The root-finding process.

C. *Shifting the Origin to Obtain Higher Accuracy*

Consider, as an example, the cubic equation with complex coefficients

$$f(z)=(b_0+jc_0)+(b_1+jc_1)z+(b_2+jc_2)z^2+(b_3+jc_3)z^3 \qquad (21)$$

and replace the variable z by $z'+r+js$. This in effect shifts the origin by an amount $r+js$ as shown in Fig. 7. The new equation in z' is

$$\begin{aligned} f(z'+r+js)=&[(b_0+b_1r-c_1s+b_2r^2-b_2s^2-2c_2rs+b_3r^3\\ &-3b_3rs^2-3c_3r^2s+c_3s^3)+j(c_0+b_1s+c_1r\\ &+2b_2rs+c_2r^2-c_2s^2+3b_3r^2s-b_3s^3)]\\ &+[(b_1+2b_2r-2c_2s+3b_3r^2-3b_3s^2-6c_3rs)\\ &+j(c_1+2b_2s+2c_2r+6b_3rs+3c_3r^2-3c_3s^2)]z'\\ &+[(b_2+3b_3r-3c_3s)+j(c_2+3b_3s+3c_3r)]z'^2\\ &+[b_3+jc_3]z'^3=\psi(z'). \qquad (22) \end{aligned}$$

Now suppose that a zero of a polynomial has been found by means of the instrument of Fig. 5, but upon inserting the zero into the polynomial, it does not reduce to zero exactly, indicating that the zero is slightly in error. If the zero which the instrument has found is $r+js$, while the actual zero is $z_n=x_n+jy_n$, different from $r+js$ by $\delta+j\epsilon$, then one of the zeros of (22) is $\delta+j\epsilon$. This is evident from Fig. 7, where $z_n=(r+\delta)+j(s+\epsilon)$, and the fact that $f(z_n)=0$. Thus, $f(z_n)=\psi(\delta+j\epsilon)=0$.

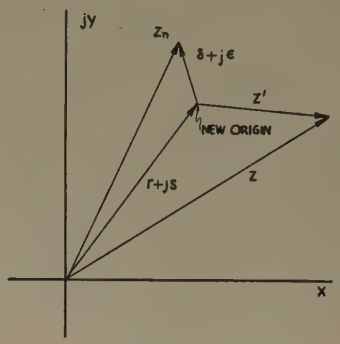

Fig. 7—Shifting the origin.

By means of (22), z_n may be found more exactly than $r+js$ by inserting r and s into (22), setting (22) into the solver, and finding $\delta+j\epsilon$. Then z_n (to a better degree of accuracy) $=(r+\delta)+j(s+\epsilon)$. Of course, δ and ϵ will be subject to errors, but the "shifting" process as well as the "stretching" process may be repeated just as many times as are necessary to get any desired degree of accuracy for the zeros.

It should be understood that the specific case of a cubic has been discussed here, but the same shifting process to obtain accurate roots can be applied to any degree polynomial. Suppose one had twelfth-degree polynomials to solve as a daily process. One would set up an equation similar to (22) for the twelfth-degree polynomial; and while one engaged in finding roots within the accuracy of the instrument, the usual type of arithmetic calculators could be used by someone else to set up the next equation to be solved for the error. Thus, this instrument could be used to a great time advantage over the usual numerical calculations.

It should also be mentioned that the use of (22), or of its higher degree counterpart, will enable the accurate generation of $f(z)$ in the vicinity of the point $r+js$. It is presumed that a large number of values in the vicinity are desired, warranting the arithmetic involved.

D. *Discussion of Distortion*

In order that any of the equations derived with regard to the complex multiplying devices be valid, no distortion can occur anywhere in the circuit with the exception of the adding amplifier when the instrument is being used to find roots. For finding roots it is recommended than an oscilloscope be used to measure e_t, and switches be arranged so that the oscilloscope may be connected to either the output of A_1 in the first involution unit, or the output of the last involution unit in the instrument to check for distortion. In cases where

$|z|<1$, the largest voltage in the involution circuit is usually at the output of A_1 in the first involution unit. In cases where $|z|>1$, the largest voltage is at the output of the last involution unit. Of course, if any coefficient a_m is such that $|a_m|>1$, then the output of the corresponding coefficient unit may be larger than either of the voltages mentioned above. As an added precaution, the applied voltage e, should be kept small, at least until a null ($e_t=0$) is approached. Then e may be increased so that e_t increases and is easier to measure. A check should be made for distortion when e is increased; but as the settings of x and y will be close to the root, the operator will now know at which point the largest voltage will appear and need check only that one point.

In generating a polynomial, distortion is not permitted at all; and since the largest voltage will usually be e_t, it should be monitored for distortion by a reliable means.

V. The Values of the Circuit Constants

This discussion presupposes an amplifier which meets the requirements mentioned in section II;[3] the amplifier must be capable of delivering 2.5 watts at about 50 volts rms.

It has already been stated that $R_1\omega C_1=1$ (see Figs. 3 and 4). Letting the operating frequency be 60 cps and C_1 be 0.003 microfarads, then $R_1=883{,}000$ ohms (slide-rule accuracy). These are merely nominal values for C_1 and R_1; the necessary relation is $R_1\omega C_1=1$. Thus, if C_1 is not exactly 0.003 microfarads, R_1 may be adjusted to make the gain of A_1 exactly $\pm j$ with the feedback loop closed. It should be noted that the magnitude of the impedance of C_1 or of R_1 is 883,000 ohms; this high an impedance will have practically no loading effect upon the amplifier preceding it.

Now consider the potentiometers P_x, P_y, P_b, and P_c. Each of these is at the output of an amplifier, except those at the input to the solver where a voltage e exists whether or not this is the applied emf. The resistance of these potentiometers cannot be so small that they will overload the amplifiers. It seems reasonable now to assume that a value of 1,000 ohms will be satisfactory in this respect. Each of these potentiometers should be helically wound with, say, 10 turns, and the shaft of each potentiometer should be equipped with a dial so that 0.01 of one turn may be read directly from the dial. Of course, all of the P_x's must be mechanically connected together as indicated by the dashed lines in Fig. 5. The P_y's are also mechanically connected so that all of them may be varied simultaneously. For the coefficients a_m to be accurately set into the solver, it is only necessary that the potentiometers P_b and P_c be linear, while for the value of z in each unit to be identical with the others, it is necessary that the potentiometers P_x and P_y be linear and that the mechanical connections be accurate—it is not necessary that the total resistance of each potentiometer be exactly that of the others. Fortunately, helical potentiometers with good linearity (0.05 per cent) are commercially available.

Having chosen the potentiometer resistance equal approximately to 1,000 ohms, R_2, R_3, and R_4 must be chosen large enough so that the voltages at the brushes are linear with brush position within reasonable accuracy. If a particular resistance is 100 times as large as the resistance of the potentiometer to which it is connected, the departure from linearity of the brush to ground voltage will not exceed 0.25 per cent. If a resistance 1,000 times as large as the potentiometer's is used, the largest departure from linearity is about 0.025 per cent. It appears that a resistance from 100,000 ohms to 1 megohm would be suitable for R_2, R_3, or R_4, depending upon the accuracy requirements; one megohm, resulting in negligible error, is recommended.

It is not necessary that the resistances R_2 in the sign changers A_2 be exactly 1 megohm, but it is essential that for a given sign changer the two R_2's be equal to each other within, say, 0.05 per cent. Thus, for each sign changer the resistances designated R_2 must be trimmed to the same value close to 1 megohm. Similarly, the three resistances R_3 in a given involution unit must be trimmed, while the resistances R_4 in the adding circuit all must be trimmed to the same value close to 1 megohm.

VI. Simplifications in the Instrument Resulting in a Circuit for Solving Polynomials with Real Coefficients Only

It will be noted that the polynomials which arise in engineering problems usually have real coefficients; it is an origin shift to a complex z which gives rise to complex coefficients. Thus, in the event that extreme accuracy is not required of the polynomial solver, the use of the origin shift may be eliminated and the instrument much simplified accordingly. It is at once apparent that the A_1 amplifiers and associated components in the coefficient units (Fig. 4) may be discarded. Furthermore, the A_2 amplifiers in the involution units (Fig. 3) and the S_y switches may be eliminated. This is not so apparent, and a few explanatory remarks are necessary.

By reducing the involution units as mentioned above, the real part of z is always negative, and the imaginary part may be either plus or minus. Choose the connections to the A_1 amplifiers of the involution units so that $z=-|x|+j|y|$. Now, since a polynomial with real coefficients has zeros in conjugate complex pairs, while $f(\bar{z})=\overline{f(z)}$, where $\bar{z}$ is the conjugate of z and $\overline{f(z)}$ is the conjugate of $f(z)$, it is apparent that it is not necessary to change the sign of the imaginary part of z either to find the zeros of the polynomial or to generate it, pro-

[3] A high-gain alternating-current amplifier with approximately 180-degree phase shift from the input to the output at the operating frequency is required. To discourage any tendency to oscillate at a frequency other than the operating frequency, a band-pass filter at the input, or output, or both, should be used. Furthermore, to eliminate "hum" (since the instrument will operate at 60 cps) the filaments of all tubes should be supplied by a direct-current source.

vided one accounts for the sign of the imaginary part of either the zero or the polynomial appropriately.

In order to change the sign of the real part of z, it is noted that if z were $|x|-j|y|$ (instead of $-|x|+j|y|$), the signs of the odd powers of z would be changed, but those of the even powers would remain the same, By changing the sign of every odd power of z by shifting the burden of the sign to the coefficient, the output of the adding circuit is as if z were $|x|-j|y|$, which enables one to deal with plus values of x. The fact that the sign of the imaginary part is minus is unimportant, but of course the remarks above on conjugates must be regarded.

VII. Conclusion

This paper describes an instrument for generating polynomials and for finding the roots, real or complex, of any polynomial, of any degree, with either real or complex coefficients, and to any degree of accuracy. It is also shown that this instrument may be built with commercially available parts.

The Measurement of Current Distributions along Coupled Antennas and Folded Dipoles*

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***Summary*—The theoretical analysis of coupled antennas is facilitated by the use of symmetrical and antisymmetrical currents. This paper presents experimental results verifying this physical concept of current on closely coupled antennas and folded dipoles.**

I. Introduction

THE THEORETICAL ANALYSIS of coupled antennas is carried out advantageously by representing the current in each element as a superposition of symmetrical (codirectional) and antisymmetrical (oppositely directed) components of current.[1] If the spacing between the elements satisfies the near-zone conditions $\beta_0 b = 2\pi 1\lambda \ll 1$, the symmetrical components maintain the far-zone field and may therefore be called the radiating or antenna currents; while the antisymmetrical components which contribute insignificantly to the far-zone field are essentially nonradiating or transmission-line currents. It is the purpose of this paper to verify experimentally this physical concept of currents in coupled antennas and folded dipoles.

II. Measuring Apparatus and Techniques

Fig. 1 is a block diagram of the measuring setup. The basic structure on which all current-distribution measurements were made consists of a coaxial line, the shield of which ends at a conducting ground plane; the extension of the inner conductor over the ground plane forms the antenna.[2] Protruding from a slot in the center conductor is a small shielded loop which can be moved along the entire length of the antenna and into the coaxial line to measure both the current distribution on the antenna and line and the standing-wave ratio on the line. In this way the impedance of the antenna is obtained. The length of the antenna may be increased by extending the inner conductor a greater distance over the plane by a rack-and-pinion movement. The second element of the coupled antenna is formed by a quarter-inch rod which is parallel to the slotted antenna and composed of threaded sections that may be adjusted in length to any integral number of centimeters. This element may be connected to or insulated from the ground plane; in the latter case the antenna is connected to a type-N connector.

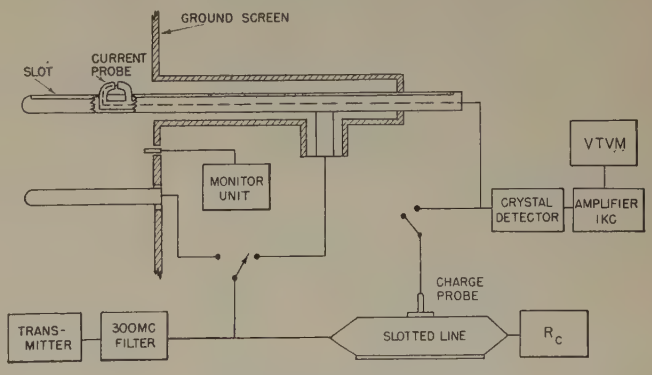

Fig. 1—Block diagram for measuring setup.

The problem is to use the same slotted antenna to measure the current distribution on both the driven and parasitic elements. By symmetry, the feed points may be interchanged so that the slotted antenna can be used as the parasitic antenna. A small charge probe, located symmetrically between the two elements, is used both as an amplitude and a phase-reference monitor so that when the two elements are interchanged,

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[1] King, Mimno, and Wing, "Transmission Lines, Antennas, and Waveguides," McGraw-Hill Book Co., New York, N. Y.; pp. 224–226; 1945.

[2] T. Morita, "Current distributions on transmitting and receiving antennas," Proc. I.R.E., vol. 38, pp. 898–904; August, 1950.

the relative amplitudes and phases of the currents on each element may be determined.

Relative phase is measured by adding the signal from the test probe to a signal obtained from a traveling probe on a slotted line terminated in its characteristic impedance. All measurements were made at 300 mc, modulated by a 1-kc signal. A 1N21B crystal and a tuned amplifier were used in the detector circuit and the voltage was read on a Ballantine vacuum-tube voltmeter.

To measure the current distribution on a folded dipole, a short-circuiting bar was placed at the ends of the coupled antennas described above. Measurements were made for coupled antennas and folded dipoles of lengths $h=\lambda/4$ and $\lambda/2$ with spacing between elements of $b=0.04\lambda$.

III. Resolution of Measured Distribution into Symmetrical and Antisymmetrical Currents

By application of the superposition theorem it is always possible to solve the problem of two coupled

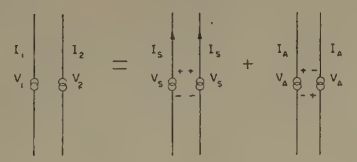

Fig. 2—Resolution of measured distribution into symmetrical and antisymmetrical currents.

antennas, center-driven by voltages V_1 and V_2, by obtaining the solutions for symmetrically and antisymmetrically driven pairs. From Fig. 2 it follows that

$$V_1 = \tfrac{1}{2}(V_S + V_A)$$
$$V_2 = \tfrac{1}{2}(V_S - V_A),$$

or

$$V_S = V_1 + V_2$$
$$V_A = V_1 - V_2.$$

Similarly,

$$I_1 = \tfrac{1}{2}(I_S + I_A)$$
$$I_2 = \tfrac{1}{2}(I_S - I_A),$$

or

$$I_S = I_1 + I_2 \qquad (1)$$
$$I_A = I_1 - I_2,$$

and

$$Z_1 = \frac{V_1}{I_1}. \qquad (2)$$

For the particular case under consideration, the second element is parasitic. Thus,

$$V_2 = 0,$$

or

$$V_S = V_A,$$

and

$$V_1 = \tfrac{1}{2}V_S,$$

so that

$$Z_1 = \frac{2V_S}{I_S + I_A} = \frac{2Z_AZ_S}{Z_A + Z_S},$$

with

$$Z_S = \frac{V_S}{I_S} \qquad (3)$$

and

$$Z_A = \frac{V_A}{I_A}.$$

In measuring, the impedance of the antenna with its coupled element, as well as the relative amplitudes and relative phases of the currents in the elements, has been obtained. It is desirable to secure the absolute amplitudes and absolute phases of the measured distributions. If V_1 is arbitrarily chosen to be 1 volt, with a phase angle of 0 degrees, it follows from (2) that

$$|I|\,\underline{|-\theta^0} = \frac{1\,\underline{|0^\circ}}{|Z_1|\,\underline{|\theta^\circ}}.$$

Therefore, the reciprocal of Z_1 gives the amplitude of current in amperes per volt, while the negative of the phase angle of the impedance gives the phase angle of the current at the gap. This establishes the absolute value of amplitude in amps per volt, and the phase of the current at any point.

With such a procedure it may be assumed that it is possible to define a unique voltage at the gap. From the point of view of the wave picture, the electromagnetic field at the gap can be represented in terms of the dominant TEM mode in the coaxial line, together with nonpropagating higher-order modes introduced at the gap, in order to satisfy the boundary condition at the discontinuity. The assumption of a voltage of $1\,\underline{|0^\circ}$ volt at the gap from measurements on the line is equivalent to neglecting these higher-order modes and representing the driving voltage only in terms of the dominant TEM mode. Theoretically, this means that the voltage assigned to the gap is actually the voltage defined back in the line, one wavelength from the gap, where only the dominant mode is present. By application of (1), the symmetrical and antisymmetrical components of current may be obtained. The symmetrical and antisymmetrical impedances may be derived from (3). Moreover, the mutual and self-impedances Z_{12} and Z_{11} are given by the following:

$$Z_{12} = Z_{21} = \tfrac{1}{2}(Z_S - Z_A)$$

and

$$Z_{11} = \tfrac{1}{2}(Z_S + Z_A).$$

IV. Results

A. Coupled Antennas

In Figs. 3 and 5 are shown the measured distributions of the magnitudes and phases of the currents on both the driven and parasitic elements of two coupled antennas, for which $\beta_0 h = \pi/2$ and π. By following the procedure developed in the foregoing section, these currents are decomposed into the symmetrical and antisymmetrical components of Figs. 4 and 6. The antisymmetrical currents may be identified with the equal and opposite currents of a two-wire transmission line. Since the symmetrical currents are equal and in phase in both elements, they may be identified with the radiating or antenna currents.

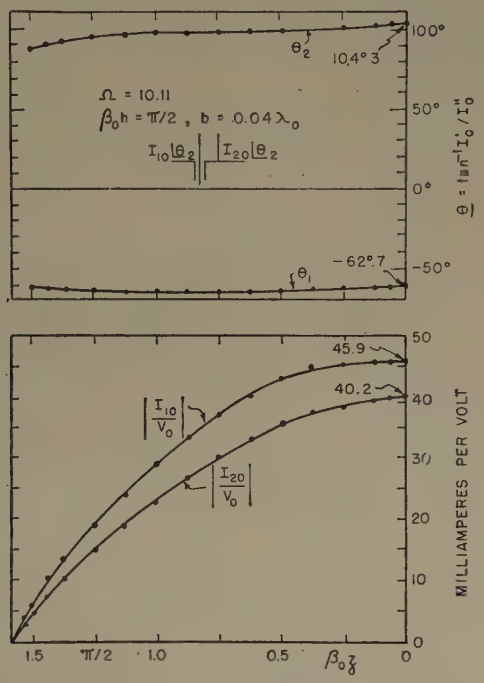

Fig. 3—Measured current distribution on coupled antenna, $h=\lambda/4$, $b=0.04\lambda$.

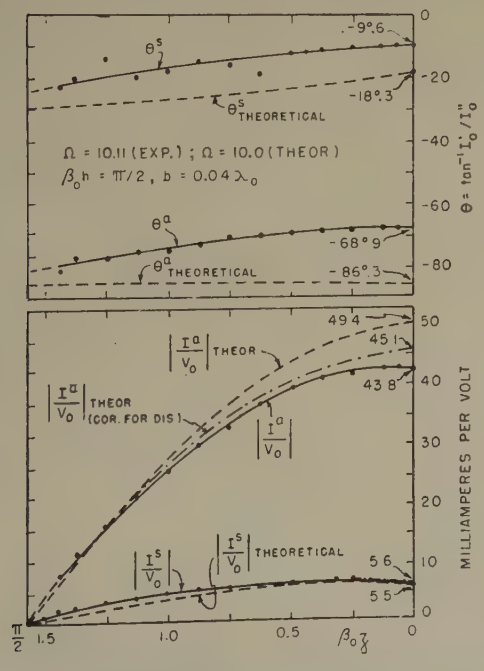

Fig. 4—Symmetrical and antisymmetrical components for coupled antenna, $h=\lambda/4$, $b=0.04\lambda$.

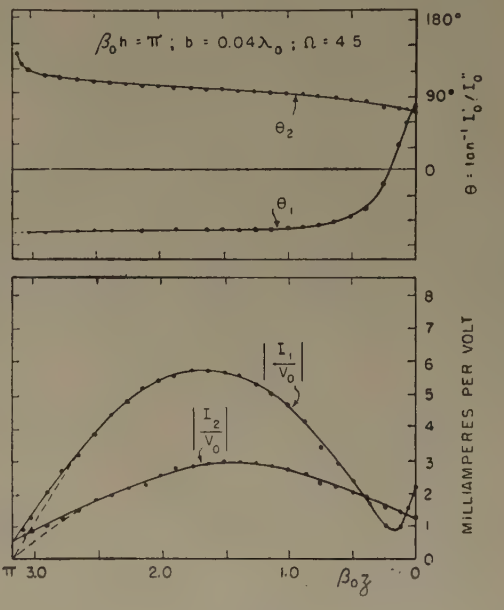

Fig. 5—Measured current on coupled antenna, $h=\lambda/2$, $b=0.04\lambda$.

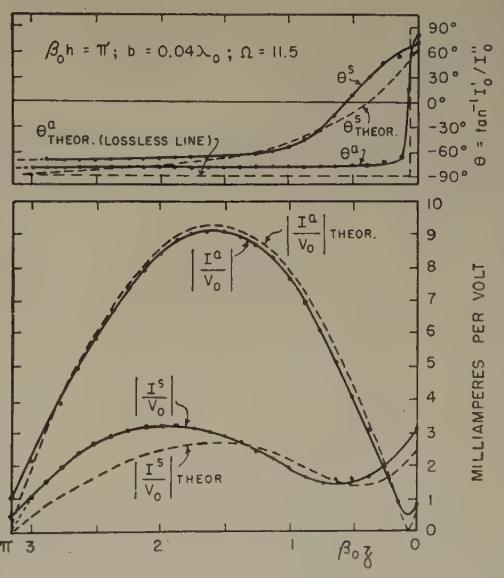

Fig. 6—Symmetrical and antisymmetrical currents for coupled antennas, $h=\lambda/2$, $b=0.04\lambda$.

It is interesting to compare the large amplitude of the antisymmetrical current with that of the symmetrical current. Since antisymmetrical components do not radiate, it is obvious that the antisymmetrical component has the effect of lowering the efficiency of the antenna if the transmission line has ohmic losses. Note that

TABLE I

$\beta_0 h=\frac{\pi}{2}$	*Experimental* $\Omega=10.11=2\log\frac{2h}{a}$	*Theoretical No Ohmic Dissipation* $\Omega=10$	*Theoretical with Added Series Resistance of 3.55Ω to Compensate for Ohmic Dissipation*
Z_1	$10.0+j19.2=21.8\ \underline{\vert 62.7^0}$	$3.2\ +j19.0=19.3\ \underline{\vert 80.5^0}$	$9.3\ +j17.9\ =20.2\ \underline{\vert 62.5^0}$
$Z_{11}=Z_{22}$	$45.8+j12.8=47.6\ \underline{\vert 15.6^0}$	$42\ \ +j19.3=46.3\ \underline{\vert 24.6^0}$	$45.6\ +j19.3\ =49.5\ \underline{\vert 22.9^0}$
Z_{12}	$41.6+j\ 1.9=41.7\ \underline{\vert 2.6^0}$	$41.4\ +j\ 9.2=42.3\ \underline{\vert 12.4^0}$	$41.4\ +j\ 9.15=42.3\ \underline{\vert 12.4^0}$
Z_S	$87.4+j14.7=88.6\ \underline{\vert 9.4^0}$	$83.4\ +j28.4=88.1\ \underline{\vert 18.8^0}$	$86.95+j28.4\ =91.4\ \underline{\vert 18.1^0}$
Z_A	$4.2+j10.9=11.7\ \underline{\vert 68.9^0}$	$0.65+j10.1=15.5\ \underline{\vert 86.3^0}$	$4.2\ +j10.1\ =11.0\ \underline{\vert 67.4^0}$
$\beta_0 h=\pi$	$\Omega=11.3$	$\Omega=10$	
Z_1	$122\ \ -j454$	$170\ \ -j352$	
$Z_{11}=Z_{22}$	$127\ \ -j782$	$52.5-j987$	
Z_{12}	$-\ 43\ \ +j494$	$52.5+j798$	
Z_S	$84.5-j289$	$105\ \ -j190$	
Z_A	$170\ \ -j1275$	$0\ \ -j1785$	

for $\beta_0 h=\pi$, the distances between minimum amplitudes are smaller for the symmetrical current distribution than for the antisymmetrical distribution. Theoretical curves[3,4] are shown for the symmetrical currents computed from the second-order solution to the integral equation; the antisymmetrical currents are compared with the sinusoidal distribution characteristic of a lossless transmission line.[3] In the theoretical formulation it is assumed that the antenna is driven by a difference of scalar potential applied by a ring generator, while the experimental model is driven by a coaxial line over an image plane. Since these methods of driving are equivalent only in the physically unavailable limit of a coaxial line with a dielectric of vanishingly small radius and a comparably small gap, only qualitative agreement is to be expected.

It is interesting to note that for $\beta h=\pi/2$ much better agreement with the experimental value is obtained if 3.55 Ω is added in series with the theoretical antisymmetrical resistance in Table I (above), to correct for the ohmic dissipation.

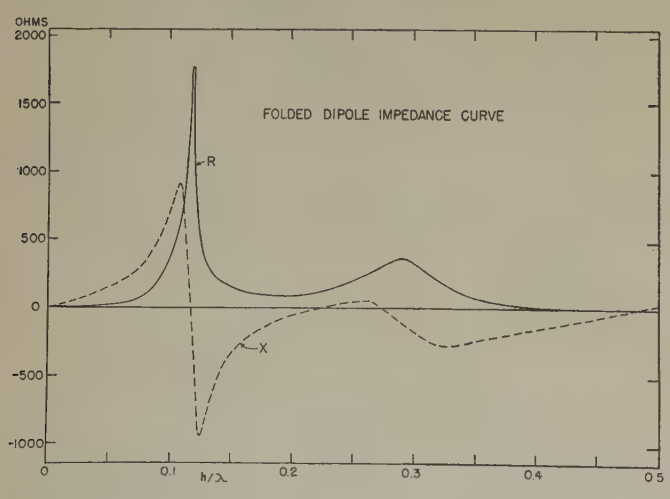

Fig. 7—Measured impedance for folded dipole, $b=0.04\lambda$.

[3] C. T. Tai, "The theory of coupled antennas and its applications," PROC. I.R.E., vol. 36, pp. 487–497; April, 1948.

[4] R. W. P. King, "Self- and Mutual Impedances of Parallel Identical Antennas," Cruft Laboratory Technical Report No. 118, Harvard University, Cambridge, Mass.; November, 15, 1950.

B. Folded Dipole

In Fig. 7 are shown the measured curves of resistance and reactance as a function of the length of the folded dipole over an image plane. The region of broad-band behavior for this structure is between points of antiresonance. For studying the behavior of the folded dipole in this range, a value of $\beta_0 h=\pi/2$ was selected. The measured distribution curve is shown in Fig. 8, and the symmetrical and antisymmetrical components in Fig. 9. The symmetrical components has a maximum at the gap while the antisymmetrical current has a maximum at the end of the antenna. The antisymmetrical current is the same as that of a short-circuited transmission line of length $l=h+b/2$, where b is the spacing between the two conductors.

A clearer picture of this concept of symmetrical and antisymmetrical currents may be obtained from a study of the phase diagram in Fig. 10. Here the voltage of the gap is taken as 1 $\underline{\vert 0^\circ}$ volts. Since the antenna is slightly

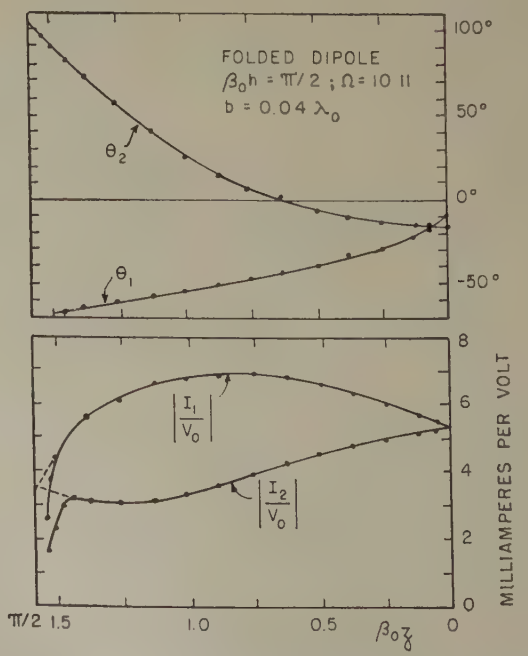

Fig. 8—Measured current on folded dipole, $h=\lambda/4$, $b=0.04\lambda$.

longer than the resonant length of a dipole, the impedance for the symmetrical component is slightly inductive and small. Accordingly, the symmetrical current at the gap is large and lags behind the voltage by

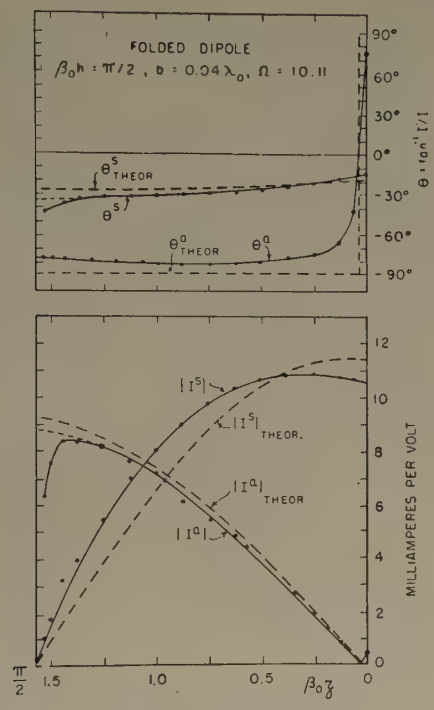

Fig. 9—Symmetrical and antisymmetrical components for folded dipole, $h=\lambda/4$.

a small angle. As we proceed along the antenna, the current amplitude decreases, falling to zero at the end, while the phase lags by a small amount as the end is approached, causing the phasor to rotate clockwise.

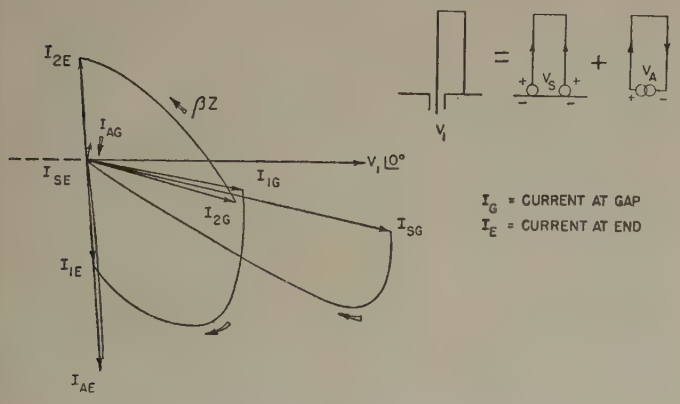

Fig. 10—Vector diagram for current distribution on folded dipole, $h=\lambda/4$.

Since the equivalent short-circuited transmission line is slightly longer than a quarter wavelength, the antisymmetrical impedance is high and capacitive. This means that the antisymmetrical current is small and leads the applied voltage by nearly 90 degrees at the gap. At the quarter wavelength from the end, phase reversal takes place, with the antisymmetrical current going to a minimum. Beyond this point the current increases sinusoidally, reaching a maximum at the short-circuited termination. The vector sum and difference of the symmetrical and antisymmetrical currents give the currents on the driven and parasitic elements, respectively. For this case the following impedances are obtained:

Experimental

$$Z_1 = 188 + j36.4$$
$$Z_{11} = 513 - j116.9$$
$$Z_{12} = -467 + j128.1$$
$$Z_S = 92.2 + j22.4$$
$$Z_A = 1{,}980 - j450.$$

In Fig. 11 we see the measured current distribution along a folded dipole, with $\beta_0 h = \pi$. Here the antisymmetrical current distribution is seen to be very much greater than the symmetrical current; hence, no reasonably accurate decomposition into symmetrical and antisymmetrical currents is possible.

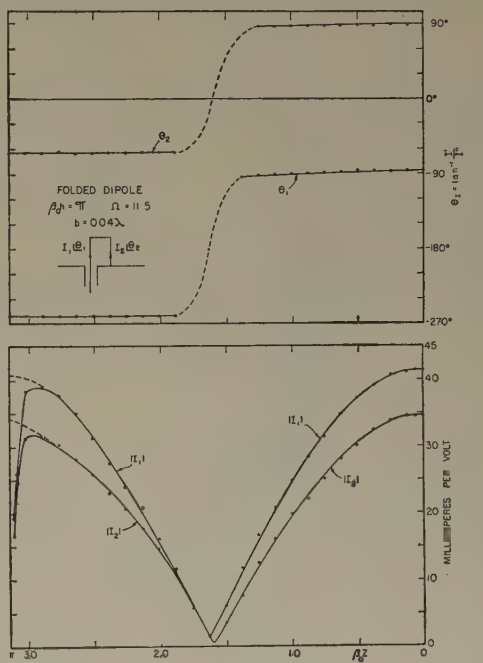

Fig. 11—Measured current on folded dipole, $h=\lambda/2$, $b=0.04\lambda$.

V. Conclusion

A method has been developed for measuring and interpreting distributions of current along both folded and parasitic dipoles. The results of the measurements have been compared with the theory, and qualitative agreement has been obtained. This is another illustration of the use of the concept of symmetrical and antisymmetrical components in physical problems.

Acknowledgments

The authors are indebted to R. W. P. King of the Cruft Laboratory, Harvard University, for his guidance in the work, and to Mrs. R. Dressler, who did part of the computing.

A High-Speed K-Band Switch*

MAURICE W. LONG†, ASSOCIATE, IRE

Summary—**A high-speed rotary three-way switch for 1.25 centimeter waves is described. An application for rapid scanning and performance characteristics are given.**

I. Introduction

THE SWITCH discussed here was designed to permit rapid scanning of a sector by means of a multiple-dish rotary antenna. For this application, each output arm shown in Fig. 1 is connected to a primary feed by an open choke-flange coupling. A stationary shorting barrier which has a window is between these open junctions. As the rotor spins with the antenna assembly, power is successively delivered to each feed while the others are short circuited. This switching arrangement reduces the required rotating speed in rapid-scan systems, thereby minimizing mechanical difficulties inherent in high-speed systems, and decreases the dead time which is present in a single antenna system.

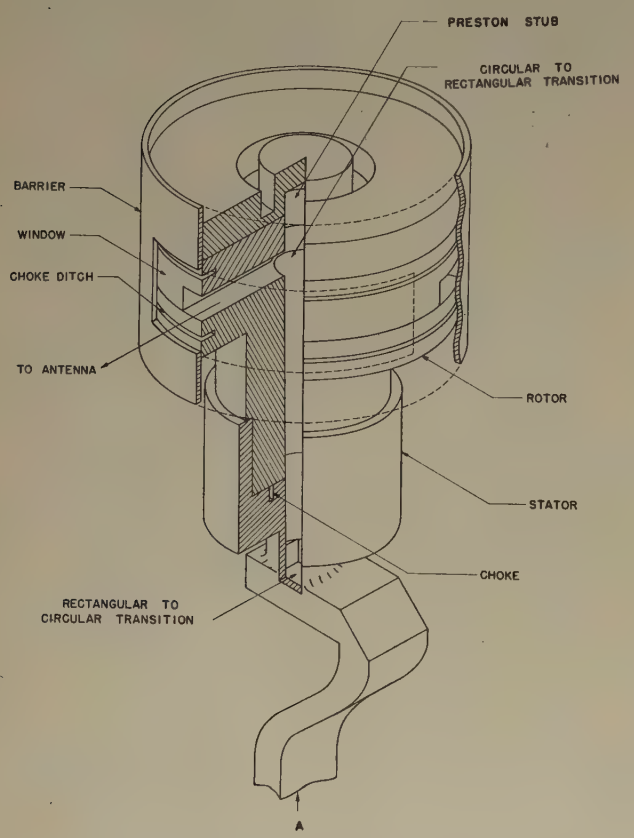

Fig. 1—Detailed drawing of three-way rotary switch.

The switch is based on a TM_{01}-mode rotary joint.[1,2] As shown in Fig. 1, TE_{10}-mode microwave energy is introduced at A and is propagated through a standard TM_{01} transition or stator into the circular waveguide section. Since the TM_{01} mode is symmetrical about the axis of the circular waveguide, the energy incident upon the output transition or stator is not a function of its position in azimuth. During the on time, a 1.25 VSWR (voltage standing-wave ratio) is not exceeded over a two per cent band. The maximum VSWR during switching is slightly less than 2. The output power variation with rotation is less than 0.05 db at any frequency within the 2 per cent band. The insertion loss is approximately 0.50 decibel.

II. Description of Switch

The rotor diameter was chosen so as to facilitate the use of broad-band matching techniques by means of inductive irises placed in the output waveguides. This method of matching to the loads separately insures that equal power be delivered to each antenna. The on time of the switch is slightly greater than twice the dead time. By sacrificing bandwidth, the switching angle may be reduced by increasing the rotor diameter by an integral number of wavelengths. Increasing the number of output waveguides will further decrease the bandwidth. An extension of the round waveguide below the rectangular waveguide, terminated by a short circuit, similar to that used in the Preston TM_{01} transition,[3] was employed to suppress the dominant TE_{11} mode within the rotor. The aperture is cut to slightly overlap two adjacent waveguides in order to reduce reflections during switching. A rectangular window has been used for simplicity; however, slanting the short sides of the window may reduce the switching VSWR. If the relative motion of the rotor and barrier window is considered, it may be seen that the barrier is a variable inductive iris during the time a window edge moves across the face of an output waveguide.

Since the field in the stator and rotor are relatively free from asymmetry, it follows that large TE_{11}-mode

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† Research Department, Georgia Institute of Technology, Atlanta, Ga.

[1] G. L. Ragan, "Microwave Transmission Circuits," McGraw-Hill Book Co., New York, N. Y., vol. 9, p. 385; 1948.
[2] See pp. 538–539 of footnote reference 1.
[3] See pp. 388–389 of footnote reference 1.

reflection coefficients are present at the transitions. Thus, cavity action is present when the round-shaft length is an integral number of half wavelengths in the TE_{11} mode. As the number of wavelengths in the round waveguide is increased, the bandwidth between resonances is decreased. Therefore, the circular waveguide is kept short to avoid resonances within the operating band. The shaft length was adjusted so as to prevent resonances and to result in impedance cancellations which minimize the over-all VSWR. In Fig. 2, the VSWR's for the stator, rotor, and complete switch are plotted versus free space wavelength.

The barrier is spaced several thousandths of an inch from the rotor face. Choke ditches are milled in the rotor face above and below the output apertures to provide a good shorting characteristic at the barrier, thereby reducing energy leakage and erratic performance. The output waveguides are then spaced a few thousandths of an inch from the barrier face. The switch is made of annealed brass and silver plated to mprove the conductivity.

ACKNOWLEDGMENTS

The author is indebted to J. E. Boyd, J. S. Hollis, R. E. Honer, and T. E. Roberts for inspiration and assistance.

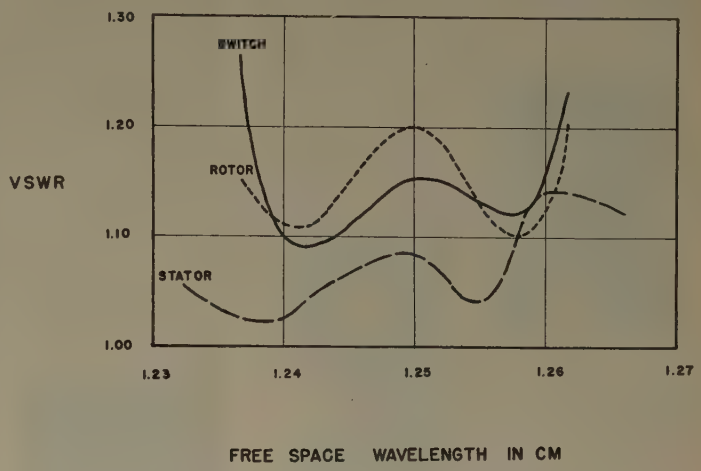


Fig. 2—VSWR versus free-space wavelength for stator, rotor, and complete switch.

I.R.E. Electroacoustics Standards: Genesis of the Glossary of Acoustical Definitions

In the May, 1951 issue of the PROCEEDINGS OF THE I.R.E., the "Standards on Electroacoustics: Definitions of Terms, 1951" appeared. Questions of credit for work done have arisen; the IRE is happy to thank the persons named below, as well as many others who contributed to the formulation of the standard and have not been mentioned. An explanation is in order:

At the end of the war the IRE Committee on Electroacoustics undertook the revision of the published IRE Standards on Electroacoustics of 1938. By the end of 1947 a "final draft" was distributed for criticism and by April, 1948 the proposed standard had been presented to the IRE Standards Committee, revised, and was ready for final action by the IRE Standards Committee. The IRE was thus quite close in 1948 to having new standard definitions of terms on electroacoustics.

In April, 1948 the American Standards Association subcommittee Z24A (sponsored by the Acoustical Society of America), having undertaken the revision of the ASA Acoustical Terminology of 1942, asked IRE to join with it. IRE agreed, and the processing of the new electroacoustics standard within IRE was stopped. Mr. Eginhard Dietze, Chairman of IRE Electroacoustics Committee, was made co-chairman of Z24A.

In 1950 the final form of a proposed standard, which was the direct responsibility of "the combined IRE Electroacoustics Committee and ASA Subcommittee Z24A on Acoustical Terminology," was adopted. For substantial reasons the IRE Standards Committee asked IRE representatives on ASA Z24 (not including Mr. Dietze, who died recently) when voting for adoption to request (but not require) an editorial qualification concerning a category of terms. (This is mentioned because these terms do not appear in the published IRE standard.)

The proposed standard from the combined group was presented (late 1950) to the IRE Standards Committee by the IRE Electroacoustics Committee for adoption and publication as an IRE standard. This is the course which would have been pursued if the Electroacoustics Committee's work up to 1948 had continued to follow IRE procedure, and had the great advantage that it would allow publication in the PROCEEDINGS so that all interested IRE members might benefit. The IRE Standards Committee requested extensive changes (these changes consisted of the omission of a group of terms; the items retained in the standard agree in wording with those of the combined IRE-ASA group report), and the result is the standard published in the May, 1951 issue of PROCEEDINGS.

The upshot of this situation may be partially summarized thus:

(1) The published IRE standard is not the ASA proposed standard, but agrees with the latter to the extent to which the former goes.

(2) Almost all the terms appearing in the IRE standard were included in the draft being circulated in 1947 by the IRE Electroacoustics Committee, but many definitions have undergone revision since then.

(3) IRE would not normally adopt or reproduce an ASA standard as its own, but in the present case the work was a joint effort of IRE on the one hand and ASA on the other.

(4) In the period between April, 1948 and Fall, 1950 many persons as well as the IRE Electroacoustics Committee worked on the standard, and to them acknowledgment and thanks are due. In particular, Dr. Leo L. Beranek, who became Chairman of ASA Sectional Committee Z24 some time after the merger of the work took place, and Mr. C. F. Wiebusch, who was co-chairman with Mr. Dietze of Subcommittee Z24A, should be singled out.

IRE members will have noticed that, preceding each standard published in the PROCEEDINGS, there are listed the names of members of the Standards Committee and of members of the originating IRE committee. The main purpose of this is to indicate *responsibility*, and only incidentally to give *credit*. However, in the present case it may be noted that of the combined group 17 were members of the IRE Electroacoustics Committee and were listed with the standard; the remaining 17 are:

Laurence Batchelder	R. F. Norris
V. L. Chrisler	R. V. Parsons
Floyd A. Firestone	H. I. Reiskind
C. W. Hewlett	M. S. Richardson
J. W. Horton	A. M. Small
T. A. Kvaas	S. P. Thompson
James J. Lamb	H. M. Trent
J. C. R. Licklider	C. F. Wiebusch

R. W. Young

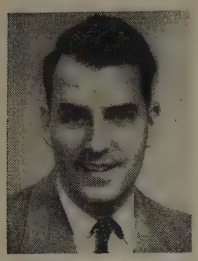
Correction

The following errors in the IRE Standards on Electroacoustics appeared on page 529 of the May, 1951 issue of the PROCEEDINGS:

line 9: 10^2 should read 10^5
line 25: 0.000045 should read 0.0000045
Table VI, last column: 1523.8 should read 1532.8

Contributors to Proceedings of the I.R.E.

William G. Abel was born in Louisville, Ky., on March 3, 1915. He received the B.S. degree in physics from Catholic University (Washington, D. C.) in 1939, and the M.S. degree in physics from Fordham University in 1947. Since 1947 he has been with the Raytheon Manufacturing Company, where he is at present engaged in research involving communications and propagation in the high-frequency band.



WILLIAM G. ABEL

❖

Sterling R. Anderson (A'41) was born in Toledo, Ohio, on December 6, 1916. He received the degrees of B.S. in electrical engineering and B.S. in engineering mathematics from the University of Michigan in 1940. Employed by the consulting radio engineer, Paul F. Godley, at Upper Montclair, N. J., from 1940 to 1942, he designed and adjusted directive antenna arrays for broadcasting stations.

STERLING ANDERSON

Since 1942, Mr. Anderson has been working on antennas and associated equipment for radio aids for air navigation at the United States' Civil Aeronautics Administration Technical Development and Evaluation Center, Indianapolis, Ind. At the present time, he is serving as chief of the antenna and propagation branch of the center.

❖

Sanborn C. Brown was born on January 19, 1913, at Beirut, Lebanon. He received the A.B. degree from Dartmouth College in 1935, and the M.A. from the same institution in 1937. He was an assistant in the Department of Physics at Dartmouth from 1935 to 1937. He held a fellowship from that college at Massachusetts Institute of Technology from 1937 to 1938, and was a teaching fellow from 1938 to 1941 and instructor from 1941 to 1944 in the Physics Department. He received his Ph.D. from M.I.T. in 1944, and since then has been a member of its physics faculty, now holding the rank of associate professor. At present he is in charge of the microwave gas-discharge work in the Research Laboratory of Electronics of M.I.T., and is Chairman of the Division of Electron Physics of the American Physical Society.

SANBORN C. BROWN

❖

F. W. Bubb, Jr. (A'44) was born on July 12, 1921, at St. Louis, Mo. He received the B.S. degree in electrical engineering with honors in 1943, and the M.S. degree in applied mechanics in 1949, both from Washington University. From 1943 to to 1948 he was successively instructor at the Massachusetts Institute of Technology Radar School in Boston; chief product engineer at the Navy division of McQuay-Norris Manufacturing Company, St. Louis, Mo., a VT fuze assembly plant; senior design engineer at the Naval ordnance division of Eastman Kodak Company, Rochester, N. Y.; and research engineer engaged in work on automatic control devices at Washington University, St. Louis, Mo. During 1948, Mr. Bubb invented and has applied for patent on an electronic instrument for measuring and controlling fluid phases and extremely low humidities. In 1948, he joined the staff of St. Louis University as an assistant professor of engineering, and was recently appointed associate profession of engineering.

F. W. BUBB, JR.

Mr. Bubb is a member of Tau Beta Pi, Sigma Xi, and Pi Mu Epsilon, and is a registered professional engineer in the fields of applied mechanics and electrical engineering.

❖

Marvin Chodorow (A'43–SM'47) was born on July 16, 1913, in Buffalo, N. Y. He received the B.A. degree in physics from the University of Buffalo in 1934, and the Ph.D. degree from the Massachusetts Institute of Technology in 1939. During 1940, he was a research associate at Pennsylvania State College. Dr. Chodorow was an instructor of physics at the College of the City of New York from 1941 to 1943, when he became associated with the Sperry Gyroscope Company as a senior project engineer. He remained at Sperry until 1947, when he joined the physics department of Stanford University, where he is now associate professor.

MARVIN CHODOROW

Dr. Chodorow is a member of the American Physical Society, and of Sigma Xi.

❖

Ralph I. Cole (A'29–SM'46) was born in St. Louis, Mo., on August 17, 1905. Shortly after receiving the B.S. degree from Washington University, St. Louis, Mo., in 1927, Mr. Cole entered Government Service as a radio engineer for the Signal Corps, engaged in research and development at their Fort Monmouth Laboratory. Projects assigned to his cognizance included direction finding and tank radio, and it was under his technical direction that the first modern tank radio was developed, using such components as Radio Receiver BC312. He is the holder of several patents concerning improvements in radio direction finding systems and special radio components.

R. I. COLE

In 1936 Mr. Cole received the M.S. degree in physics from Rutgers University. He assumed charge of Research and Development of Radio Direction Finding and Fighter Control Equipments intended for Signal Corps and Air Force use in 1940. With the advent of hostilities, Mr. Cole was directly commissioned a Major in the Army of the United States and assigned to the Signal Corps Laboratory as Officer in Charge of the Radio Direction Finding Branch of the Eatontown Signal Laboratory. He was promoted to Lieutenant Colonel, Signal Corps, in July, 1944. Transferring to the Air Forces on February 1, 1945, he was placed in charge of all engineering activity concerning the Development of Ground Electronics Equipment for the Air Forces at Watson Laboratories.

Mr. Cole returned to civilian life in June, 1947, after having received the Army Commendation Ribbon and the Legion of Merit for his efforts in the research and development field. He is still active in Air Force Reserve matters and holds the rank of Colonel. Mr. Cole is now Technical Director, Electronics Development Division, Rome Air Development Center, Rome, New York.

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James A. Craig was born in 1907, at Hackensack, N. J. After graduation from high school, he was employed by the Bell

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Telephone Laboratories for seven and a half years. During this time he attended Cooper Union Night School of Engineering, and graduated in 1932 with the degree of B.S. in electrical engineering.

JAMES A. CRAIG

From 1932 until 1936 Mr. Craig was engaged in aviation as a pilot and mechanic. After this period he did teletype-maintenance work at Hearst Radio, Inc. He was then transferred to Finch Telecommunications Laboratories, where he was engaged in development work on picture transmission and facsimile.

In 1938 Mr. Craig joined the Link Radio Corp., where he is currently employed as systems engineer.

❖

Leonard C. Edwards (A'50) was born on December 27, 1925, at Lowell, Mass. He received the B.S. degree in electrical engineering from the University of New Hampshire in 1949. Since that time he has been with the Raytheon Manufacturing Company, where his work has been concerned with communication, propagation, and pulse technique in the high-frequency band. He is a member of Tau Beta Pi and Phi Kappa Phi.

L. C. EDWARDS

❖

Carl E. Faflick was born in Cleveland, Ohio, on March 10, 1922. He attended Oberlin College from 1940 to 1943 and from 1946 to 1947, and in 1943 received the B.A. degree. He served in the Signal Corps, United States Army, from 1942 to 1946, and during 1944 and 1945 took the Harvard - Massachusetts Institute of Technology Army Electronics course. In 1947 he was an instructor in physics at New Mexico State College.

CARL E. FAFLICK

In 1949 Mr. Faflick received an S.M. degree from Harvard University, where he has been a teaching fellow and research assistant. At present he is in Europe as a Sheldon Traveling Fellow. He is a member of Sigma Xi.

Harry H. Goode was born in New York, N. Y., on July 1, 1909. He received the B.S. degree at New York University in 1931, the B.Ch.E degree from Cooper Union in 1940, and the M.A. degree in mathematics from Columbia University in 1945. He served as assistant to the Deputy Commissioner of the New York City Health Department from 1935 to 1938, as assistant director for statistics on the Commission for Study of Crippled Children, New York City, from 1938 to 1940, and as statistician-in-charge of the Central Statistical Division at the New York City Department of Health from 1940 to 1942.

HARRY H. GOODE

During World War II Mr. Goode was a research associate at Tufts College, where he worked chiefly in probability applied to war problems. In 1946 he joined the staff of the Office of Naval Research at the Special Devices Center, and, as research section head, computer consultant, and special projects branch head, did work in computer research, simulation, training, aircraft instrumentation and control design, antisubmarine warfare, and weapon system design.

Early in 1950 Mr. Goode became the head of the Systems Analysis and Simulation Department of the Willow Run Research Center at the University of Michigan. At present he is chief project engineer for the Center, whose work is concerned with research and development on complex systems.

Mr. Goode is a member of the American Association for the Advancement of Science, the Institute of Mathematical Statisticians, the American Mathematical Society, the Association for Computing Machinery, and Mu Alpha Omicron.

❖

Karl G. Hernqvist was born in Boras, Sweden, on September 19, 1922. He was graduated from the Royal Institute of Technology, in Stockholm, Sweden, in 1945. Since August, 1946, Mr. Hernqvist has been employed by the Research Institute of National Defense in Stockholm, except for the period from October, 1948, to November, 1949, when he was associated with the RCA Laboratories, Inc., in Princeton, N. J. At RCA he was a trainee under the auspices of the American-Scandinavian Foundation.

K. G. HERNQVIST

In addition to his work at the Research Institute of National Defense, Mr. Hernqvist is pursuing graduate studies at the Royal Institute of Technology.

❖

Henry C. Hurley (A'40) was born in Star, N. C., on November 22, 1903. He received the B.S. degree in electrical engineering from North Carolina State in 1927.

HENRY C. HURLEY

Following graduation, Mr. Hurley was employed in the radio engineering department of the General Electric Company, Schenectady, N. Y. From 1930 to 1938, he was employed by the RCA-Victor Company at Camden, N. J., where he worked on special apparatus and test-equipment development and design. Since 1938, he has been engaged in the development of radio navigational aids at the United States' Civil Aeronautics Administration Technical Development and Evaluation Center, Indianapolis, Ind.

❖

Hugh F. Keary (A'46) was born in Ireland in 1899. He attended radio technical school in 1920, and received the United States' first-class commercial operator's license. As a marine radio operator, he spent five years aboard United States' merchant vessels.

HUGH F. KEARY

From 1925 to 1929, Mr. Keary served as junior engineer at RCA radio central stations at Rocky Point and Riverhead, Long Island, N. Y. He resigned from this position to join the laboratory of the Wired Radio, Inc., Ampene, N. J., where he assisted in the development and testing of broadcast systems for transmission over power-line networks.

From 1932 to 1934, Mr. Keary was employed by the DeForest Radio Company and the Hygrade Sylvania Company as radio-test engineer in the development and testing of radio-communication equipment, and from 1935 to 1937, he was development and test engineer in the manufacture of air navigational aids and communication equipment for the Radio Receptor Company, N. Y.

In 1937 Mr. Keary joined the staff of the Bendix Radio Corporation, Washington, D. C., and served as development and test engineer for radio-range systems and com-

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munication equipment. He resigned in 1943 to assist in the design and development of vhf navigational aids systems for the United States' Civil Aeronautics Administration, Technical Development and Evaluation Center, Indianapolis, Ind.

❖

Maurice W. Long (S'47–A'51) was born on April 20, 1925, in Madisonville, Ky. He received the B.E.E. degree from the Georgia Institute of Technology in 1946, and the M.S.E.E. degree from the University of Kentucky in 1948. The next two years were spent in graduate studies at the University of Kentucky and Columbia University.

MAURICE W. LONG

Mr. Long was employed for part of 1946, 1947, and the summer of 1948, as a research assistant at the Georgia Institute of Technology. From 1947 to 1949 he was an instructor of electrical engineering at the University of Kentucky. At present, he is a research engineer in the Electronics Research Laboratories, at the Georgia Institute of Technology.

Mr. Long is a member of the American Society of Engineering Education, Sigma Pi Sigma, and an associate member of Sigma Xi.

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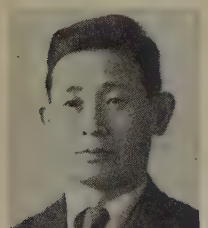
Kiyoshi Morita was born in Tokyo, Japan, on March 18, 1901. He was graduated in 1921 from Tokyo Higher Technical School, which was chartered later as the Tokyo Institute of Technology, and won the Tejima honor prize the same year. In 1933 he received a doctorate in electrical engineering from the Tokyo Imperial University. In 1941 he was appointed professor at the Tokyo Institute of Technology, where he was primarily concerned with the development of measuring apparatus for dielectric loss, paraboloidal reflectors, triple-line feeders, and the like.



KIYOSHI MORITA

Since then he has given lectures on high frequency and electronic engineering.

Dr. Morita won an honor prize for his contribution on uhf techniques from the Nippon Radio Kyokai in 1946. The same year he became chief of the Special Committee for UHF Measurement, sponsored by the Ministry of Education, and was active in the development of the wattmeter for uhf. Since 1949 he has headed the Committee for the Development of Vacuum Tubes for Microwaves.

In April, 1950, he was sent to the United States by the Galioa Fund. From that time until June, 1950, he visited Cornell University, Brooklyn Polytechnic Institute, the University of Michigan, and other universities, from which he studied the American engineering educational system. He returned to Japan and contributed much to the improvement of teaching in the universities there. He also did actual work, in collaboration with many American professors sent to Japan, in the engineering section of the Institute for Educational Leadership.

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For a photograph and biography of TETSU MORITA, see page 1463 of the November, 1951, issue of the PROCEEDINGS OF THE I.R.E.

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Peter G. Sulzer (A'46) was born in Media, Pa., on August 3, 1922. He attended Drexel Institute of Technology in Philadelphia from 1940 to 1943. During that time he also spent one year with the Westinghouse Radio Division in Baltimore, Md.

PETER G. SULZER

Mr. Sulzer was in the United States Army Signal Corps from 1943 to 1946, engaged for the most part in ionospheric work. He received the B.S. degree in 1947, and the M.S. degree in 1949, both in electrical engineering, from the Pennsylvania State College, where he had been engaged in designing ionosphere equipment. Since September, 1949, Mr. Sulzer has been employed at the Central Radio Propagation Laboratory of the National Bureau of Standards in Washington, where he is concerned with ionospheric instrumentation.

❖

Vernon B. Westburg (S'46–A'49) was born in Chicago, Ill., on October 9, 1920. He received the degree of B.S. in electrical engineering from Purdue University in 1941, and the M.S. degree in 1942.

V. B. WESTBURG

From 1942 to 1946 Dr. Westburg was employed by Zenith Radio Corporation, where he worked on radar indicator circuits and antennas for automotive radio. From 1946 to 1948 he was the recipient of the Sylvania Electric Products fellowship at Stanford University, and in 1950 he received the Ph.D. degree in electrical engineering. At present he is a research engineer in the vacuum-tube laboratory of Stanford Research Institute.

Dr. Westburg is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and the American Institute of Electrical Engineers.

❖

Philip Woodward was born at Gnosall, England, on September 6, 1919. He received the B.A. degree in mathematics from Oxford University in 1942, and since 1941 has been employed by the Telecommunications Research Establishment in England, where he is now a Principal Scientific Officer. During the war, he was trained in research under professor H. G. Booker of Cornell University, who was then in charge of the theoretical work at the Telecommunications Research Establishment.

PHILIP WOODWARD

Mr. Woodward's work was devoted to research on the theory of antennas, radio propagation, and turbulent diffusion in the atmosphere. His mathematical interests now concern the theory of probability, the Fourier transformation, and the theory of information.

Correspondence

More on Telepathic Communication*

Hollmann's[1] correspondence brings to light the following: Loefgren of The Royal Institute of Technology, Stockholm, Sweden carried out extensive pioneer work in the radio sciences, which also extended to brain radiations. As his assistant, I was in correspondence, during 1936 and 1937, with Cazzamalli, and received various papers and reports with circuit diagrams and photographs of Cazzamalli's equipment, as well as oscillograms of brain waves. The emotional excitation of the patient via "radio transmission" resulted in jerks in the curve of the oscillogram, more or less as the corresponding case would be, using conventional encephalographic methods. From the material presented no definite conclusion could be drawn at that particular time as to whether or not true brain-wave radiation was at hand, particularly since Cazzamalli's equipment was rather nonprofessional. There was no uncertainty in Cazzamalli's statements, however, that he actually received communications at a distance from active human brains without the use of wires.

Much more interesting, perhaps, is an earlier contact I had in this field as the guest of von Ardenne of Berlin, Germany, a well-known radio scientist. In his residence, converted into a huge and well-equipped four-story electronics laboratory, one room was used for brain-wave tests. Here, in 1929, von Ardenne demonstrated various short-wave receivers suitable for brain-wave reception, and he claimed successful results. These receivers, superheterodyne and super-regenerative types, went down to 5 or 10 meters, and were equipped with the Ardenne-developed "Loewe" tube following the detector. After confronting von Ardenne again in 1937 with the Cazzamalli results, correspondence developed in which von Ardenne claimed to have received brain-wave vhf communication on special receivers during previous years. It may be, therefore, that Cazzamalli made the discovery of the radiation phenomena in medical science around 1923, while von Ardenne was the originator of modern receiving and measurement methods of electromagnetic brain waves around 1927.

Just as research work in Stockholm had begun to check Cazzamalli's and von Ardenne's results, both of these scientists declared that no further correspondence could be carried on since this field of research had been made secret by Mussolini and Hitler.

As the author was connected, in 1947, with the United States Air Force, as the Chief Communications Laboratory, Cambridge Field Station, he strove to have the USAF make funds available for triple-continued research investigations. These would include (1) modified encephalographic recording of the patients' conditions, and (2) microwave and infrared reception of the radiation; these technical approaches being associated with such techniques as may develop from (3) a rigorous study of the extra-sensory perception results obtained by Duke University. The latter's pioneer work in esp provided the missing link (not just the most exciting controversy of modern scientific thought) and also grounds on which *the radio scientist enters the field of human psychology* to unite with the psychologist in research work. My requests for funds in 1947 were not approved by the USAF because of the urgency of other research work.

No doubt this is the right time for serious research work along the lines indicated above. Such work is bound to yield not only startling, but also highly useful results. Thanks to Shannon and others a firmly grounded information theory, applicable to this field, is available, as was indicated by Mr. Bibbero[2] in the original correspondence on these pages.

HARRY STOCKMAN
Electronics Consultant
Waltham, Mass.

* Received by the Institute, July 25, 1951.
[1] H. E. Hollmann, "Telepathic communication," PROC. I.R.E., vol. 39, p. 841; July, 1951.
[2] R. J. Bibbero, "Telepathic communication," PROC. I.R.E., vol. 39, pp. 290–291; March, 1951.

Checking Analogue Computer Solutions*

An important problem faced by the users of analogue computers is the checking of solutions. Although the digital solution of sample cases is likely to be both tedious and expensive in coding and checking time, particularly for complicated problems, nevertheless the desirability of such parallel solution was several times mentioned at the recent IRE National Convention.

In the course of testing our analogue computer, we devised a direct check on analogue solutions which, so far, has obviated the need for digital check solutions. The method will catch mistakes in scale factors and machine setup, if the error they cause is somewhat greater than the general level of precision expected from the machine solution.

Essentially, the check consists of substituting the machine solution back into the original set of equations. In the case of a set of differential equations, the procedure is to record all the variables and their various derivatives. The machine values are converted back into mathematical quantities by applying the scale factors. If, on substitution, one or more equations do not yield identities, either a scale factor error exists in those equations or the proper terms are not being summed by the solving amplifier. As the final logical step, it is necessary to check, by numerical integration, whether each derivative is the integral of the next lower derivative.

E. LAKATOS
Bell Telephone Laboratories, Inc.
Murray Hill, N. J.

* Received by the Institute, March 29, 1951.

Mu-Beta Effect Calculator*

An additional application of some value has been found for the calculator described by Felker.[1] The stability margin, described by Duerdoth,[2] is a measure of the closeness of approach of the $\mu\beta$ locus to the critical point $1\underline{|}0$. The advantage which the stability margin offers is ease of measurement: It is, as Duerdoth shows, simply the ratio of gain with feedback to gain without feedback, and it provides the most convenient production test of stability.

The stability margin is defined as

$$\sigma = 20 \log_{10} | \mu_f/\mu |,$$

where

$$\mu_f = \mu/(1 - \mu\beta),$$

and μ, β have the usual meanings. After some rearrangement, we obtain

$$\sigma = 20 \log_{10} \frac{-1/\mu\beta}{1 - 1/\mu\beta}.$$

This equation may be compared with Felker's equation (3), which is equivalent to

$$\gamma_{db} = \frac{-\mu\beta}{1 - \mu\beta}.$$

It is thus clear that the calculator can be used equally to determine σ and γ. The stability margin is obtained for any particular $\mu\beta$ by finding the mu-beta effect corresponding to $-|\mu\beta|$ db instead of $|\mu\beta|$ db.

As an example we may consider the servoamplifier of Felker's paper. The stability margin obtained in the "normal gain" and "12 db up" conditions is tabulated in the following:

normal gain

ω	$-\lvert\mu\beta\rvert$ db	θ	σ db
1.5	−17	37°	−16
2	−13	44°	−11.6
4	−5	56°	−3.4
10	4	57°	+1.5
20	15	23°	+1.6

gain 12 db up

ω	$-\lvert\mu\beta\rvert$ db	θ	σ db
1.5	−29	37°	−29
2	−25	44°	−25
4	−17	56°	−16.5
10	−8	57°	−6.6
20	+3	23°	+7.1

Duerdoth recommends that a production limit of +6 db should be used. It is seen at once that with gain up 12 db this amplifier does not fall within limits.

It has been found that this direct use of the calculator for stability margin offers worth-while advantages in designing amplifiers in terms of the final test criterion.

H. JEFFERSON
Telefonaktiebolaget
L. M. Ericsson
Stockholm, Sweden

* Received by the Institute, May 14, 1951.
[1] J. H. Felker, "Calculator and chart for feedback," PROC. I.R.E., vol. 37, p. 1204; October, 1949.
[2] W. T. Duerdoth, "Some Considerations in the Design of Negative-Feedback Amplifiers," *Proc. IEE* (London), vol. 97, Pt. III, p. 138; May, 1950.

Correspondence

Preferred Numbers*

In the February, 1951 issue of the PROCEEDINGS OF THE I.R.E. there appeared a guest editorial on preferred numbers by Mr. A. F. Van Dyck. This was followed by a second guest editorial on the same subject by Mr. Virgil Graham. The writer of the following communication, Mr. John B. Moore, presents in the following an analytical commentary on the entire selection and utilization of preferred numbers. The information in his letter should be of interest to the members of the Institute and to those committees of the Institute concerned with the use of preferred numbers.—*The Editor.*

During roughly the past year there has been published a number of articles, editorials, and pamphlets dealing with the question of using so-called "preferred numbers" for sizes or values of items to be carried in stock. The aim is laudable. There seem, however, to be two basic questions that need to be answered in any specific case:

1. Is a geometric, rather than an arithmetic, series suited to the practical requirements of the particular case?
2. What should be the basic step ratio?

Question 1 is the basic question, in any particular case, and is the one with which this present discussion will deal primarily. Before proceeding to it, however, let us briefly review some of the geometric or logarithmic series and bases that have been referred to in other published discussion.

Step Ratios

It will suffice to comment briefly, as follows, regarding the bases of certain existing series:

ASA	$\sqrt[20]{10} = 1.122$
RTMA	$\sqrt[24]{10} = 1.100$
Brown and Sharpe (AWG) wire gauge	$\sqrt[6]{2.005} = 1.123$
Decibel	$20 \times \log_{10} 1.122$

The ASA plan adheres strictly to the decimal system, whereas the RTMA plan uses a decimal base and a duodecimal (12) root. The latter evidently is advocated chiefly because it results in a series that fits nicely into a pattern of ±20- or ±10- or ±5-per cent tolerances—an established pattern in certain lines—and results in no rejects. In view of other practical considerations, it is a question if these particular tolerance values should be considered so sacred. These could be increased slightly to fit the ASA-sponsored series of "preferred numbers." There then would be the not inconsiderable advantage that only one set of so-called "preferred numbers"—odd and confusing at best—would have to be remembered or looked up.

The Brown and Sharpe (AWG) wire gauge uses the basic ratio $\sqrt[6]{2}$ for the smaller and medium sizes, then departs from the geometric concept and follows an essentially arithmetic and decimal system for the larger sizes, expressed in circular mils rather than in gauge numbers.

The decibel corresponds very closely to the loss in one mile of so-called "standard cable," which latter was the practical unit of telephone transmission loss or gain before adoption of the bel and decibel nomenclature.

Geometric or Logarithmic versus Arithmetic

The really basic question, in any particular case, is whether the practical requirements of actual use will be best met by an arithmetic or a geometric series of values. This warrants serious consideration.

Of the four geometric or logarithmic series mentioned above, the Brown and Sharpe wire gauge (AWG) and the decibel have been used and generally accepted for a good many years. The reasons for this are that first, they provide the required geometric series having practical ratios for the specific applications concerned, and that, secondly, in their practical everyday use, both of them are essentially simple arithmetic series.

That last statement warrants a bit of explanation. In using the Brown and Sharpe (AWG) wire gauge, the practical man almost invariably specifies by gauge number. He does not state exact diameter or cross section carried to three or more significant figures. He does not need to. The gauge numbers give him a simple and consecutive arithmetic series by which he can specify and obtain exact sizes that follow a geometric but unmemorizable series of values. So, with an absolute minimum of mental strain, he gets exactly what he wants.

The decibel provides a logarithmic ratio or geometric series, of practical size steps, and yet requires the practical user to mentally manipulate only a simple arithmetic system of values having the decimal arrangement to which he is accustomed by training and by use in his daily life.

Consider our monetary system. As an application of the decimal system, it is based on the fact that humans found it convenient to add and subtract by using the ten fingers on their two hands. Read that sentence carefully. It brings out the fact that our natural method of computation is addition or subtraction, and the units or bases employed therein are 1, 2, 5, and 10. Except for the 25 cent piece and the $2.50 gold coin, our monetary system fits that pattern exactly. That is the basis of the average person's mathematical processes.

To be of practical usefulness, away from the drawing board or the machine shop, sizes and values must be such that they can be referred to in terms of numbers closely associated with, or simply related to, the basic numbers 1, 2, 5, and 10. This requires that geometric or logarithmic series, involving odd and unmemorizable values, should be dealt with in some manner such as illustrated by the decibel system or the Brown and Sharpe Wire Gauge. These both provide the practical man with an easily remembered and easily used arithmetic system.

Conclusions

Geometric or logarithmic series would seem to be best adapted to such cases as: (1) dimensions of wire or sheet-gauge sizes, (2) nominal dimensions of unfinished stock that must be machined to finished dimensions, (3) sizes of items that are not used in additive combination, and (4) fields in which the ratio rather than the absolute value is of primary importance.

Arithmetic series, of either the consecutive-numbers type or the decimal (1, 2, 5, and 10) type, would seem to be generally preferable in most cases to those listed in the preceding paragraph.

Resistors, such as those used in the circuits of electrical and electronic equipment, should be rated and sold according to an arithmetic decimal series of values. If, however, a geometric series is to be used—for certain technical reasons—industry should at least be consistent and use a basic ratio which corresponds with that of the decibel system. It just so happens that this also agrees with the ASA proposal.

Recommendation

If the electronics industry wants a geometric or logarithmic series of values, for resistors, it would seem most consistent to rate such resistors in dbr—decibels above and below one ohm. As contrasted with any new series of so-called "preferred numbers," the dbr series of values would appear to offer many advantages.

Addendum

In certain published discussions regarding so-called "preferred numbers," there seems to have been considerable stress placed on the practical utility of the Brown and Sharpe wire gauge. Some elaboration of this point appears warranted.

The Brown and Sharpe wire gauge employs the basic ratio $\sqrt[6]{2.005}$. This base—2—is one of the natural preferred numbers, if I may call it that, in the 1, 2, 5, and 10 decimal system used daily by practically every individual, regardless of the extent of his or her formal education.

In view of the foregoing, it would seem to be in line with other discussions, and also with the requirements of practical use, to incorporate the basic 2-to-1 ratio in any system of so-called "preferred numbers." Fortunately, the well-established db system does just this. Reference to the following tabulation will bring out this point.

db (Ratio)	*Exact Values*	*Rounded Values*
0	10	10
2	12.59	12.5
4	15.85	16
6	19.95	20
8	25.12	25
10	31.62	32
12	39.81	40
14	50.12	50
16	63.10	63 or 64
18	79.43	79 or 80
20	100	100

Note that the 2-to-1 relationship prevails throughout the list of rounded values.

J. B. Moore
66 Broad St.
New York, N. Y.

* Received by the Institute, June 5, 1951.

Institute News and Radio Notes

IRE Officials Attend Western Convention

Discussing Western IRE Convention agenda are (from left to right): A. R. Ogilvie, Chairman of the IRE San Francisco Section; L. J. Black of Berkeley, Convention Chairman; George Bailey of New York, National IRE Executive Secretary; R. A. Isberg of San Francisco, Chairman of the Convention's first Technical Session; and A. V. Eastman of Seattle, Director of the IRE 7th Region.

1951 Western IRE Convention Huge Success

The 1951 Western IRE Convention and 7th Annual Electronic Exhibit, held in the Civic Auditorium, in San Francisco, on August 22, 23, and 24, proved to be one of the most successful of all Western Conventions. The attendance at the exhibit exceeded 8,000, with over 1,100 registrants at the IRE Convention. The excellent quality of the exhibit coupled with the well-planned technical sessions provided the attendants with a complete view of the activities in the electronic field. The technical program featured a new theme wherein each session was arranged to cover a specific topic of a current interest in the electronic field. The chairman of each session was a leading authority on the subject under discussion. This well-balanced technical program gave a maximum of information for those in attendance. The climax of the technical sessions came Friday evening with the presentation of a paper by D. E. Foster on, "System Aspects of Color Television," with approximately 500 persons attending.

The Convention was also extremely successful for the wives of the IRE members. The highlight of the women's activities was a fashion show staged by Nelly Gaffney in the Peacock Court of the Hotel Mark Hopkins, with Paul Speegle as mirth-provoking commentator. The ladies were presented with leis that had been flown in from Hawaii especially for this occasion.

Plans are now underway for the 1952 Western IRE Convention and 8th Annual Pacific Electronic Exhibit to be held in the Municipal Auditorium, Long Beach, Calif., August 27, 28, and 29, 1952. Arrangements should be made now to insure that all IRE members, who wish to attend the Convention, may do so. Plans and information of the 1952 Convention will be carried in the future issues of the Proceedings.

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Group on Transistors Organized

Formation of a group on transistors, to assist its committee on electronics to establish sound policies for the development and functional application of transistors by the Armed Services, has been announced by the Research and Development Board of the Department of Defense.

Included in the group are six representatives from university and industrial laboratories: J. W. McRae (A'37–F'47), Bell Telephone Laboratories, chairman; E. F. Carter (A'23–F'36), Sylvania Electric Products; E. W. Engstrom, (A'25–M'38–F'40), RCA Laboratories; I. A. Getting (SM'46), Raytheon Manufacturing Company; A. G. Hill (SM'46–F'50), Massachusetts Institute of Technology; and G. F. Metcalf (A'34–M'38–F'42), General Electric Company.

The military service members are: Colonel C. J. King (A'30–VA'39–SM'50), Office, Chief Signal Office; Colonel G. F. Moynahan (S'49–A'50), Office of the Assistant Chief of Staff, Department of the Army; J. M. Bridges (SM'47), Bureau of Ordnance; C. L. Stec (S'35–VA'39–SM'49), Bureau of Ships; H. V. Noble (A'34–M'35–SM'43), Wright Air Development Center, Dayton; and E. W. Samson (M'47–SM'51), the Air Force Cambridge Research Center.

The first meeting of the group was held on October 11, 1951, New York, N. Y. At this time the group discussed its functions, responsibilities, and methods of operation.

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NBS Meeting on Storage

A Symposium on Williams Electrostatic Storage will be held at the National Bureau of Standards, Washington, D. C., on December 13 and 14, 1951. Those interested in this type of storage who wish to participate should contact the conference chairman, J. H. Wright, Electronics Division, National Bureau of Standards, Washington 25, D. C.

Calendar of COMING EVENTS

IAS-ION-IRE-RTCA Conference on Air Traffic Control, Astor Hotel, New York, N. Y., January 30.

1952 IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y., March 3–6.

Radio Component Show, London, England, April 7–9.

Radio and Television Show, Manchester, England, April 23–May, 3.

IEE Television Convention, London, England, April 28–May 3.

IRE-AIEE-RTMA Symposium on Progress in Quality Electronic Components, Washington, D. C., May 5–7.

IRE National Conference on Airborne Electronics, Hotel Biltmore, Dayton, Ohio, May 12–14.

4th Southwestern IRE Conference and Radio Engineering Show, Rice Hotel, Houston, Tex., May 16–17.

1952 IRE Western Convention, Municipal Auditorium, Long Beach, Calif., August 27–29.

New Italian Publication

Announcement has been made of a new Italian publication, *Marconi*, published by Marconi Societa Industriale, Via Hermada 2, Genova-Sestri, Italy. It is a quarterly review of telecommunications and electronics techniques. Technical articles are published in Italian; summaries in Italian, English, and German.

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IRE Emporium Section Seminar Has Largest Attendance

The 12th Annual Summer Seminar of the Emporium Section of the IRE, held August 17 and 18, 1951, enjoyed the largest attendance in its history. Average session attendance was over 200, with nearly 100 out of town guests. A total of 175 were entertained at the picnic held Saturday afternoon.

The technical section of the program was divided into two main parts consisting of a papers' session Friday evening, and a Reliable Tube Symposium Saturday morning. Speakers and members of the Symposium panel were all outstanding men in the electronics industry who had made noteworthy contributions to the reliability programs now so important to the Armed Forces. Information on the program schedule can be found on page 971, in the August, 1951, issue of the Proceedings.

1952 IRE Convention Set for March 3–6

March 3–6, have been selected as the dates for the largest and most important radio engineering meeting and show in 1952—the IRE National Convention. The Waldorf-Astoria Hotel and Grand Central Palace in New York City will again be the scene for the 4-day program of technical sessions, exhibits, and social activities.

This Convention takes on special significance for Institute members in that 1952 marks the 40th anniversary of the founding of IRE. Many of the Convention activities will be keyed to this important milestone and to the Convention slogan, "Forty years sets the pace," making it an event of particular interest to the membership.

The opening meeting of the Convention will be the Annual Meeting of the Institute which, in honor of the anniversary, will feature an interesting presentation of 40 years of IRE by Dr. Alfred N. Goldsmith and John V. L. Hogan, co-founders of IRE, entitled, "The IRE: From Acorn to Oak." This meeting will be held at 10:30 A.M., Monday, March 3, in the Jade Room of the Waldorf-Astoria Hotel. The Radio Engineering Show, enlarged to include four floors of exhibits, will again occupy the Grand Central Palace, two blocks south of the Waldorf on Lexington Avenue. Sessions of the extensive technical program will be held in both locations and the nearby Belmont-Plaza Hotel.

The social activities will start on the first evening of the convention, March 3, with a "get-together" cocktail party, which this year will be held in a new and more spacious location, the Grand Ballroom of the Waldorf-Astoria. On the following day the world-famous Starlight Roof of the Waldorf will be the scene for the traditional President's Luncheon in honor of Dr. Donald B. Sinclair, the IRE President for 1952. Tables will be set aside for members of the Professional Groups in order that they may become better acquainted with engineers in their own field of interest. Charles E. Wilson, Director of Defense Mobilization, will address the Annual Banquet on Wednesday evening, March 5, in the Grand Ballroom. The recipients of the 1952 IRE Awards will be introduced at that time. For the wives of members and visitors an entertaining 4-day program of tours, plays, and fashion shows is being prepared. Members are urged to buy their tickets now. Ticket prices are as follows: Banquet, $12.00; Luncheon, $5.75; Cocktail Party, $3.80.

Full details of the program, including 100-word summaries of technical papers, will appear in the February issue of the PROCEEDINGS.

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Technical Committee Notes

The **Standards Committee,** under the Chairmanship of Ernst Weber, held a meeting on October 11, 1951. Acting-Chairman Ernst Weber, in the absence of Chairman A. G. Jensen, reviewed certain items that had been discussed at the meeting of the Administrative Committee on October 10. At this meeting, Chairman A. G. Jensen appointed a Subcommittee to consider the need of a **Technical Committee on Pulse Systems.**

A Meeting was held by the **Committee on Modulation Systems** on September 18, Chairman W. G. Tuller presiding. This Committee has found it necessary to revise its scope of activity and is anticipating a change in its title. Recommendations of these changes will be submitted to the Standards Committee for their approval.

The Executive Committee approved the change in the title of the IRE Technical **Committee on Mobile Communications** to the IRE Technical **Committee on Mobile Communications Systems.** This Committee has broadened its scope of interests. The revised scope is as follows: Responsibility for mobile communication system matters such as general engineering studies, frequency allocations, and the consideration of new developments or techniques which may have a major effect on the engineering of mobile communication systems; To act as consultant with RTMW, RTCA, FCC, and other bodies as may desire its assistance on engineering matters of mobile communication systems.

Under the Chairmanship of H. E. Roys, the **Sound Recording and Reproducing Committee** held a meeting on October 13. The Subcommittee on Mechanical Recording, of this Committee, convened in the morning of October 13, joining the main Committee in the afternoon. Lincoln Thompson of the Subcommittee reported on their activities. Preparations are underway to outline tasks on the calibration of frequency records, and plans are being made to write material on the amplitude method of measurement.

H. R. Terhune has been appointed to serve as alternate to A. F. Pomeroy, who is the IRE Representative on the ASA Sectional Committee Y-1 Abbreviations.

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Professional Group Notes

Delegates from all of the **IRE Professional Groups** attended the organizational meeting on November 9, of the Technical Program Committee, which is formulating plans for the **IRE National Convention** on March 3–6, 1952. The Committee Chairman, W. H. Doherty of Bell Telephone Laboratories, Murray Hill, N. J., will assist the Professional Groups in arranging the Symposia to be sponsored by the various Groups at the Convention.

The **IRE Professional Groups on Airborne Electronics, Audio, Vehicular Communications, and Antennas and Propagation** are now levying assessments on their members for publication expenses. Arrangements are being made by the **IRE Professional Groups on Instrumentation and Information Theory** to adopt the assessment payment for their respective Groups.

Plans to hold a membership drive are being made by the **IRE Professional Group on Airborne Electronics** during its participation in the IAS-IRE-RTCA-ION Annual Convention on Electronics and Aviation, January 28 to February 1, 1952, at the Hotel Astor, New York, N. Y. This Group's meeting will take place on January 30, 1952.

The recently formed **IRE Professional Group on Information Theory,** headed by Acting Chairman Nathan Marchand, is now in the process of drawing up its Constitution and is also making plans for a membership drive. The Group is tentatively planning a symposium to be held in January, 1952, and expects to sponsor a session at the IRE National Convention in March, 1952.

The IRE Professional Group on Nuclear Science held a very successful symposium on December 3 and 4, at the Brookhaven National Laboratory, Upton, L. I., in cooperation with the Atomic Energy Commission. Full details on the papers presented, the banquet, and the panel discussion highlighting the Conference may be found on page 1343, of the October, 1951, issue of the PROCEEDINGS.

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RDB Announces New Program

The Research and Development Board, Department of Defense, has received the recommendations of a group created by the Board in December, 1950, to look into the question of reliability of military electronic equipment and to recommend measures which will insure more reliable performance with a minimum of maintenance. Based upon these recommendations, RDB has established a clearing house for reliable information which will be responsible for the collection and dissemination of such information to laboratories concerned with government work. A. F. Murray, Radio and Television Consultant, Washington, D. C., who headed the previous study, and M. Barry Carlton of the RDB secretariat have been assigned the task of monitoring future research and development programs in this field. Mr. Carlton's title is that of, RDB, Coordinator of Reliability.

The Secretary of Defense and the Chairman of RDB have issued statements to the Military Department emphasizing the importance of this problem.

According to RDB officials concerned, improvement in reliability must include all the following links in the chain leading finally to the application of the equipment in the field: military characteristics, experimental models, specifications, manufacturing control procedures, service tests, final inspection, packaging and shipping, storage, installation, operational use, and maintenance. Consequently, the combined efforts of the Munitions Board, Joint Chiefs of Staff, the three Services, and the Research and Development Board are required. These organizations are represented in the group.

The Military Reliability Program can be effective only if it has the backing and cooperation of industry. It is vital that the precepts of reliability are disseminated to and carried out by the electronics industry upon which the Department of Defense depends for research, development, and high quality control during reliability production.

IRE People

Robert M. Page (SM'45–F'47), superintendent of Radio Division III at the Naval Research Laboratory, has returned recently from a three-month survey of electronics developments in Germany. He was employed as technical consultant to the Military Security Board, the Office of the High Command for Germany. His mission, sponsored by the State Department, was to establish closer working relations with German scientists, thus aiding mutual interchange of scientific information. Dr. Page visited 58 university and commercial laboratories while in Germany.

ROBERT M. PAGE

Dr. Page was born on June 2, 1903, in St. Paul, Minn. He received the B.Sc. degree in 1927 from the Hamline University and the M.A. degree from the George Washington University in 1932. In 1943 he received an honorary Doctor of Science degree from the Hamline University. He is the holder of several awards including the United States Navy Civilian Service Award, The Citation O.S.R.D., and the President of the United States Certificate of Merit.

In 1947 Dr. Page received the IRE Fellow Award for, "recognition of his pioneering achievements in solving some of the early problems of basic importance to radar." He has been a member of the IRE Board of Editors since 1946.

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Robert W. Annis (S'47–A'51), **William C. Coombs** (S'33–A'35–VA'39), and **Charles A. Culver** (M'20–SM'43), have recently been appointed to the physics department staff of the Southwest Research Institute, San Antonio, Tex. The appointments were announced by **Paul Erlandson** (SM'50), the Institute Physics chairman.

Mr. Annis a senior research physicist from Champaign, Ill., is a specialist in electrical engineering, radio, and radio direction finding. He holds a Master of Science degree from the University of Illinois.

Mr. Coombs, supervisor of the measurements laboratory, is an authority in the fields of radio direction-finder design for intelligence intercept-, navigation-, and military-countermeasures application, radio development for production, and electronics development in physical research.

Dr. Culver, senior physicist, whose studies include courses at the University of Cambridge, Eng., specializes in the fields of electroacoustics, electrical and physical measurements, and optical, x-ray, and mass spectroscopy. Dr. Culver is the author of several technical books.

William A. Edson (M'41–SM'43) has been named Director of the school of electrical engineering at the Georgia Institute of Technology, it was recently announced.

WILLIAM A. EDSON

Dr. Edson, a native of Burchard, Neb., was born October 30, 1912. He studied electrical engineering at the University of Kansas and received the B.S. and M.S. degrees in 1934 and 1935, respectively. He then attended Harvard University on a fellowship, receiving the degree of Dr. Sc. in communication engineering in 1937. Following this, he joined the Bell Telephone Laboratories as a member of the technical staff but resigned that position to become assistant professor of electrical engineering at the Illinois Institute of Technology. He later returned to the Bell Laboratories to engage in research for the Army, working on the development of the microwave echo box, a device for testing and maintaining radar systems.

Dr. Edson accepted the position of professor of physics at the Georgia Institute of Technology in 1945, transferring to professor of electrical engineering in 1946, the position he held until the present appointment. He holds several patents in connection with oscillators and resonators, and has contributed numerous articles to technical periodicals in his field. He is a licensed engineer in Georgia and a consultant to the United States Bureau of Standards.

Dr. Edson is active in various professional and educational organizations including the American Physical Society, the American Association for Advancement of Science, the American Society for Engineering Education, and the National Society for Professional Engineers. He has served as Chairman of the IRE Committee on Standards of Piezoelectricity, and Chairman of the Subpanel on Frequency Research and Development Board. He is the past Chairman of the IRE Atlanta Section.

❖

Elmer W. Engstrom (A'25–M'38–F'40) has been named as Vice-President in charge of the RCA Laboratories Division, according to an announcement by Brigidier General David Sarnoff. Dr. Engstrom has been Vice-President in charge of research of the RCA Laboratories Division since 1945, and prior to this he served 2 years as Director, supervising research and engineering which resulted in wartime advances in radar, television, radio, and other electronic developments. He had previously served for 13 years in various RCA research positions.

ELMER W. ENGSTROM

Dr. Engstrom was born on August 25, 1901, in Minneapolis, Minn., and received the B.S. degree in electrical engineering from the University of Minneapolis in 1923. He then joined the staff of the General Electric Company, where he worked on transmitters, receivers, and sound motion pictures.

Dr. Engstrom has been a member of numerous IRE committees, including the Board of Editors, Awards, and Nominations. He served on the IRE Board of Directors in 1949. In June, 1949, he received an honorary degree of Doctor of Science from the New York University for his contributions as a research engineer.

❖

Allen F. Pomeroy (A'42–SM'43), a member of the technical staff of the Bell Telephone Laboratories at Murray Hill, N. J., met with experts from other countries at Montreux, Switzerland early in November to discuss graphical symbols for use on drawings. The President of the United States National Committee of the International Electrotechnical Committee appointed Mr. Pomeroy as the United States member of the Committee of Experts of Technical Committee 3 (Electrical Graphical Symbols).

ALLEN F. POMEROY

While in Europe he visited organizations manufacturing and using microwave communication equipment in England and Switzerland.

Mr. Pomeroy has been with the Bell Telephone Laboratories since his graduation from Brown University in 1929. Since 1941 he has been engaged primarily in the design and testing of microwave components such as are used in the New York to San Francisco radio relay system now utilized for telephone service and to bring television programs from the Pacific coast. This system was developed at the Murray Hill Laboratory of Bell Telephone.

Mr. Pomeroy served as chairman to the IRE Symbols Committee in 1949–1951, and is currently the Institute Representative on the Drawing and Symbols Correlating Committee of the American Standards Association. He is also Co-chairman of the ASA Sectional Committee on Graphical Symbols, and was recently appointed the industry liaison member of the Standard Drawing Practice Committee of the Munitions Board Standards Agency in Washington, D. C.

His Institute activities have included work on the Annual Review, Circuits, Papers Review, and Standards Committees.

IRE People

Trevor H. Clark (A'32–SM'45) has been appointed as director of the division of Military Research and Development and special consultant to the physics department at the Southwest Research Institute, San Antonio, Tex. He was formerly with the Federal Telecommunication Laboratories, Nutley, N. J.

TREVOR H. CLARK

Mr. Clark is the holder of many patents on electronic devices. His special fields include vacuum tubes, communication equipment, microwave relay systems, radio-direction finders, electronic countermeasures equipment, research administration, and manufacturing methods. He was one of four scientists selected to establish the United States Laboratories of the International Telephone and Telegraph Company, and has held a number of technical and administrative positions in the foreign and domestic research development and manufacturing subsidiaries of that organization. In 1948 he was named assistant to the president of the Federal Telephone and Radio Corporation of Clifton, N. J. More recently he has been active in introducing new developments of the Federal Telecommunication Laboratories, particularly microwave links and television broadcasting. Mr. Clark was awarded the United States Navy Certificate of Commendation for his work in direction finders during World War II.

A native of Kansas, Mr. Clark received the B.A. degree from the Friends University in 1930, and the M.S. degree from the University of Michigan in 1933. He has been a member of various IRE Committees and served on the IRE Board of Directors in 1950. He is a member of the American Institute of Physics, the Accoustical Society of America, and the Armed Forces Communication Association.

❖

Maxwell K. Goldstein (A'30–SM'46) has been appointed as vice president and technical director of the Balco Research Laboratories, Newark, N. J. He was formerly associated with the Air Navigation Development Board.

M. K. GOLDSTEIN

Dr. Goldstein received his doctorate degree from the Johns Hopkins University in 1933, and subsequently was engaged in the development of automatic remote indicating systems for antiaircraft gun control apparatus and radio navigation aids. In 1939 he joined the Naval Research Laboratory and for a number of years was in charge of its radio direction-finder work; he later became the head of its navigation section.

In 1947 Dr. Goldstein was awarded the Distinguished Civilian Service Award by the Secretary of the Navy, "for distinguished contributions to the Naval Service in developing high-frequency direction finding as a vital weapon for combating the German submarine menace during the crucial Battle of the Atlantic."

Dr. Goldstein is a member of Sigma Xi.

❖

Charles B. Jolliffe (M'25–F'30), who has served as Executive Vice-President in charge of RCA Laboratories Division since December, 1945, has been elected to the position of Vice-President and Technical Director of RCA. In his new position, he will be responsible for the development of long-range plans for RCA and generally will supervise the execution of such plans by the division and subsidiary companies. In addition, he will co-ordinate broad engineering policies and will direct the representation of RCA in technical matters before the various public and governmental bodies.

CHARLES B. JOLLIFFE

Dr. Jolliffe, a native of Mannington, W. Va., was graduated from West Virginia University with a B.Sc. degree in 1915 and the M.Sc. degree in 1920. He was awarded a Ph.D. degree in 1922, at Cornell University, and in 1942 he received an honorary LL.D. degree from West Virginia University. He then served as a physicist in the Bureau of Standards' radio section and later became chief engineer of the Federal Radio Commission.

He first joined RCA as engineer in charge of its frequency bureau in 1935 and, subsequently, he was named chief engineer of the RCA Laboratories and assistant to the president of RCA Victor in 1941 and 1942, respectively. In September, 1942, he became vice president and chief engineer of the RCA Victor Division.

Dr. Jolliffe has been a member of many IRE Committees and has also served on the IRE Board of Directors in 1936–1937, and again in 1944.

❖

LaVerne R. Philpott (SM'48) has been appointed as chief of the Electronics Division of the Balco Research Laboratories. He was formerly with the Air Navigation Board.

A native of Nebraska, Dr. Philpott received his B.S. degree from the College of Idaho in 1925, and later worked as a research engineer at the Westinghouse Research Laboratories from 1928 to 1934. He then went to the United States Naval Research Laboratories where he remained until 1947.

In 1945, Dr. Philpott was awarded an honorary D.Sc. degree from the College of Idaho for his work in radar, and in 1947 he was awarded the Certificate of Merit by the President of the United States for his contribution to the design of the first United States Naval radar.

Dr. Philpott is also the holder of the Distinguished Civilian Service Award.

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F. W. Tatum (A'43–SM'47), professor of electrical engineering at the Southern Methodist University, Dallas, Tex., has been named Chairman of the Department of Electrical Engineering at S.M.U.

F. W. TATUM

Professor Tatum, a native of Texas, received his technical education at Columbia University, where he graduated with the B.S. and M.S. degrees in electrical engineering, in 1935, and 1946

From 1935 to 1947 he was associated with the American District Telegraph Company and held the position of engineering supervisor at the time of his resignation to join the faculty at S.M.U.

Professor Tatum is a member of the American Institute of Electrical Engineers, the American Society for Engineering Education, and the Texas Society of Professional Engineers.

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Robert Hertzberg (A'46), long active in the technical magazine field as writer, editor, and publisher, has established a consulting publications and public relations service for radio manufacturing and merchandising firms and their associated advertising agencies, in Jackson Heights, N. Y. Their service includes counsel on the preparation of military manuals and instruction books.

ROBERT HERTZBERG

Mr. Hertzberg worked as a radio feature writer for New York newspapers during the early days of broadcasting and later became managing editor of *Radio News*, advertising manager of the Wholesale Radio Service Company, Incorporated, and, most recently, executive editor of *Mechanix Illustrated*.

Mr. Hertzberg was born on February 26, 1905, in New York, N. Y., and studied at the College of the City of New York, and Columbia University. He was commissioned in the Signal Corps Reserve for contributing to the development of the Army Amateur Radio System in the middle "20's," and was called to active duty in 1940. He served for more than five years in the United States and Europe, and after VJ Day was released to inactive status with the grade of colonel.

Mr. Hertzberg is a member of the Armed Forces Communications Association, the Quarter Century Wireless Association, and the New York Technical Section of the Photograph Society of America.

James Harold Weiner (M'50) has been promoted to the grade of Colonel, according to information received from the Air Defense Command Headquarters, Ent Air Force Base, Colorado Spring, Colo. He is now serving as Assistant Director of Communications and Electronics at ADC Headquarters.

Before entering the service in 1942, Colonel Weiner attended the Lowell Institute of Cambridge, in 1932–1934, studied at the Boston University until 1936, and was employed as a communications engineer for the New England Telephone and Telegraph Company.

Colonel Weiner has been awarded the Legion of Merit, the Army Commendation Ribbon, the American Defense Service Medal, and the American Campaign Medal. He is a native of Winthrop, Mass.

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Raymond S. Timm (A'47–M'50), formerly of the Programs Research Division, Office of Naval Research, has been named as electronics engineer at the Balco Research Laboratory, Newark, N. J.

A native of Michigan, Mr. Timm received his B.S. degree in electrical engineering in 1942, at the Lawrence Institute of Technology, and later did graduate work at the University of Maryland.

Books

Short Wave Wireless Communication by A. W. Ladner and C. R. Stoner

Published (1951) by John Wiley & Sons Inc., 440 Fourth Ave., New York 16, N. Y. 703 pages+8-page appendix+6-page index+xvi pages. 417 figures. 5¼×8½. $8.00.

Mr. Ladner was formerly principal of the Marconi School of Wireless Communication and superintendent of instruction, Marconi's Wireless Telegraph Co., Ltd. Mr. Stoner, now a reader in electrical engineering at the University of London, was also formerly associated with Marconi's Wireless Telegraph Co., Ltd.

This is the fifth edition of a book which was first published in 1932. The present edition differs from the fourth by the deletion of three chapters, and substitution of three new chapters, which are of greater current interest. Brief summaries of the chapters of the text follow.

The introduction outlines the requirements of communications systems and includes some historical data. This is followed by a chapter on sound and vision signals, one of the new chapters, which discusses the physiological and mathematical characteristics of sound and vision signals. A statement on page 37 that, "there is no immediate prospect of the transmission of color pictures," might be open to question.

This is followed by a chapter on modulation, with consideration of noncarrier, carrier, suppressed carrier, phase, frequency, and various pulse methods. This is a rather unusual approach, since ordinarily, the subject of modulation follows a discussion of methods of producing waves. It is perhaps unfortunate that the authors retain the term "ether" in their discussion. Two chapters on the propagation of short and ultra-short waves follow, which are excellent summaries of the essential features of propagation phenomena, the ionosphere, and related phenomena. A chapter is then devoted to the general aspects of radio-frequency lines, with reference to impedance matching with stubs, tapered lines, and quarter-wave lines. The second of the new chapters gives a brief account in the field of waveguides, and this is followed by two chapters on antennas and antenna arrays, which begin with the concept of an antenna as a nonterminated line. This covers various phases of antenna design, including arrays.

The next five chapters, which are largely of a circuit nature, include tuned power amplifiers; oscillators, the frequencies of which are determined largely by circuit elements external to the tube, e.g., tank circuits, crystals, and RC networks; electron oscillators, which depend more directly on the electron beam, e.g., magnetron, klystron, Barkhausen-Kurtz, among others; modulation, amplitude, frequency, and pulse; and reception, with considerations of noise, selectivity, sensitivity, and the general characteristics of receivers for various types of modulated signals. The discussions of these sections are mainly theoretical, with frequent reference to schematic diagrams.

Following is a chapter dealing with commercial receivers which gives the specialized practices used in special types, and another chapter on radio telephone circuits discusses specialized commercial equipment, although it also outlines the requirements for single-sideband, suppressed-carrier, and other systems.

The third new chapter is on radio telegraph circuits, and the book then closes with a chapter on some typical commercial equipment. In general, the material dealing with principles is clearly expressed. The material which deals with detailed commercial practice seems to be somewhat out of place in a work intended as a text.

This book will be found useful by practicing engineers, and would serve as a useful reference book for students in their radio and communication courses. Its use as a text in such courses at the college level is seriously questioned.

Samuel Seely
Department of Electrical Engineering
Syracuse University
Syracuse, N. Y.

Electromagnetic Waves by F. W. C. White

Published (1950) by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 103 pages+2-page index+2-page appendix+viii pages. 25 figures. 4¼×6¼. $1.25.

The fourth edition of a monograph published originally in 1933, this book surveys briefly the fundamentals of electromagnetic theory, Maxwell's field equations, Lorentz's equations of motion, the theory of dispersion, and the propagation of radio waves.

It is written in strictly classical style similar to that of Jean's text, although much abbreviated, and has been revised only slightly to cover the results of studies carried out by Sir Charles Darwin into the influence of electromagnetic waves on the charged particles of materials through which they pass.

The text employs Gaussian units throughout. Vector analysis is used very sparingly. Very little work appearing in the literature since 1933 has been included.

The book may serve quite well as a survey text for readers interested in obtaining a birdseye view of problems and methods of attack in this field. The specialist, however, will not find it particularly helpful.

Lloyd T. DeVore
General Electric Co.
Syracuse, N. Y.

Theory and Design of Television Receivers by Sid Deutsch

Published (1951) by McGraw-Hill Book Co., 330 W. 42 St., New York 18, N. Y. 521 pages+14-page index+xix pages. 376 figures. 6×9¼. $6.50.

Mr. Deutsch is an instructor in advanced television at the Madison Institute in Newark, N. J.

This book, the first of its type, attempts to meet the need of the practising television-design engineer and of the senior or graduate electrical engineer for a coverage of television-receiver design which includes supporting theoretical background

Books

For the most part, the author has done a very good job. Chapter 6, "Detector and Automatic Gain Control Circuits," Chapter 7, "Video Amplifiers and D-C restorers," and Chapter 9, "Synchronizing Section," are excellent in their completeness and clarity of exposition. Chapter 10, "Electrostatic Deflection and Focusing," Chapter 11, "Magnetic Deflection and Focusing," Chapter 12, "Power Supplies," Chapter 13, "Automatic Frequency Control," Chapter 15, "Direct- and Projection-Viewing Systems," are adequate in their treatment and coverage. The foregoing chapters are supported by Chapter 1, "Television Standards," and Chapter 16, "Television Receiver Servicing." The latter includes an excellent pictorial treatment of the effects of various receiver faults.

The author is weakest in his discussion of the rf and IF portions of the television receiver (Chapters 2, 3, 4, 5, 8, and 14). Some specific criticisms follow:

Chapter 2, page 57, is misleading in its discussion of transit-time versus lead-inductance loading. In general, for the two types discussed, cathode-lead inductance has a larger effect on input resistance than transit time and the limitation on the use of the 6AC7 is not loading of the previous stage but self-resonance of the input circuit which occurs at a considerably lower frequency.

In Chapter 3, under the discussion of IF gain on page 80, stability and maximum gain are not considered; this is a serious omission. In the same chapter, on pages 90 and 91, where series-tuned coupling circuits are described, the conclusion that the response curve has approximately the same shape as a single-tuned circuit is incorrect in that the effect of the shunt capacity on the inductance is omitted, an effect which produces a response curve having an "S" shape with a minimum at a higher frequency.

The discussion of antennas in Chapter 4 seems to this reader quite inadequate and cursory. Here on pages 150 and 160, the importance of maintaining a balance of each wire to the shield in a shielded pair is neglected and a rather loose statement is made concerning compensations for the unbalance of a coaxial line by rotating the antenna. On pages 119 to 123, there is a discussion of various antenna-input circuits. An unsupported statement is made that the width of the response curve at the image frequency will be approximately four times the IF bandwidth. This certainly does not hold for the multiple resonance of the semi-distributed circuits. The circuit diagrams all show blocking condensers in the antenna lead-in and do not show the requisite shunt-leakage path required for static protection. Also, the gain figures given for the examples are misleading and unduly high in that the maximum stable gain that can be obtained at 200 megacycles is substantially less. On page 126, under the discussion of "Local Oscillator Circuits" the statement is made that "The correct mode of oscillation is assured through the use of the Colpitts type of circuits." This is a bit of wishful thinking. In the discussion of the oscillator, no mention is made of the importance of high-C circuits in the minimizing of frequency drift, and this is another notable omission.

In Chapter 5, under "Video I-F Section," the entire discussion is of a 21-megacycle IF, and there is no mention of the RMA standard of 41.25-megacycle IF which has been standard for more than a year, and has been under discussion for the past three years. Another serious omission in the choice of the intermediate frequency is the lack of consideration of the second-order effects which have been so troublesome with present-day television receivers, particularly those employing 20-megacycle IF.

Likewise Chapter 8 on "The Sound Section," and Chapter 14, "Intercarrier Sound Reception," contain no mention of the problems introduced by a 41.25-megacycle IF. The discriminator circuit shown on page 271 is believed to be a Conrad circuit, and is incorrectly attributed to Travis. In the discussion of intercarrier-sound reception, the author seems unfairly prejudiced against the system, and fails to point out the improvement in reception which can be obtained with intercarrier-type receivers by tuning the picture signal to the top of the IF curve.

The author must be criticized, also, in a more general way, for the scarcity of reference material, and for his failure to indicate outside support for many of the statements made.

In summation, the author has attempted to cover a large field, and, on the whole, has done so in an excellent fashion.

JOHN D. REID
American Radio and Television, Inc.
North Little Rock, Ark.

Electronics by Jacob Millman and Samuel Seely

Published (1951) by McGraw-Hill Book Co., 330 W. 42 st. New York 18, N. Y. 559 pages+16-page index+22-page appendix+ix pages. 392 figures. 6×9¼. $7.25.

Mr. Millman is associate professor of electrical engineering at The City College of New York, and Mr. Seely is Chairman of the Department of Electrical Engineering at Syracuse University, Syracuse, N. Y.

This book, a second edition, is an improved and modernized version of an outstanding book which in its original form very successfully correlated physical electronics and engineering electronics.

Starting with the fundamental processes of physics, the authors squarely face the problems of electronics in sufficient detail to give the reader an excellent background. With this foundation, they describe the electronic behavior of many practical devices.

By concentrating primarily on the electronic aspects of these devices, they have covered a large field remarkably well. The problem of motion of charged particles in the electric and magnetic fields is carried on through applications to practical devices, such as the cathode-ray tube, the klystron, the betatron, and the FM cyclotron. Electron phenomena in metals is traced from the Fermi-Dirac-Sommerfeld function to contact potential, barrier layer rectifiers, and electron emission. The several mechanisms of electron emission, field emission, photoelectric emission, thermionic emission, and secondary emission are discussed, and applications are given to every important kind of commercial tube. Fundamental processes in gases are used to explain the behavior of practical gas tubes of all sizes, including the ignitron and excitron.

Although this book is primarily intended as a textbook to set the ground work for specialized courses in communications, electron-tubes, industrial electronics, etc., it would be a welcome addition to the reference shelf of most practicing engineers. Familiarity with the calculus and with elementary differential equations is assumed. The presentation is from the engineering viewpoint and presupposes a working knowledge of the basic principles of alternating-current theory, including elementary Fourier analysis.

This reviewer is favorably impressed by this book. By their clear presentation and agreeable style, the authors have produced an easily readable book which successfully bridges the seldom filled gap between fundamental theory and engineering applications.

R. R. LAW
RCA Laboratories Division
Princeton, N. J.

Principles of Electrical Engineering by W. H. Timbie and Vannevar Bush

Published (1951) by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 609 pages+8-page index+8-page appendix+ix pages. 417 figures. 5½×8½. $6.50.

W. H. Timbie is Professor Emeritus, Electrical Engineering and Industrial Practice, Massachusetts, Institute of Technology, Cambridge, Mass. Vannevar Bush is president of the Carnegie Institution, Washington, D. C.

This is the fourth edition of a text book for college student use which first appeared twenty-nine years ago. While the first edition treated all fundamental concepts from the viewpoint of the power engineer, the new edition approaches these fundamental concepts from the various viewpoints of the electrical engineers in many specialized fields of power, communication, or electronics. The problems included in each chapter likewise reflect this treatment. They are presented in such a way that they will appear up to date many years from now, even though the fields continue to advance at a rapid rate. In only a few instances does the text or the problems refer to values or equipment which has been superseded.

The new edition sets forth modern theories; advanced methods for analyzing and solving electric and magnetic problems and their relation to engineering circuit analysis. The information is presented in a manner which is easy to read and understand, and the exertion needed by a student to cover any assignment is thereby eased.

Books

It is interesting to note various warnings given as to probable errors due to improper use of terms, as in the case of the decibel. An attempt is made to avoid incomplete or colloquial engineering expressions even though some, such as "ohm per mil-foot," are in fairly common use. Yet it is noticed that no reference was made to "potentiometer," which commonly is used in the shortened form "pot," to indicate a variable resistor used as a voltage divider.

The Index is presumably adequate for its purpose, although this reviewer would prefer some expansion of it. The Appendix carries the usual tables for conductor sizes, current-carrying capacities, temperature constants, etc., as well as conversion factors. One wonders why the Appendix does not include some brief data as to time, place, and occupation of early pioneers such as Maxwell, Weber, Ampere, Volta, Gauss, and others whose names denote some electrical quantity, law, or characteristic. In some of the rewritten or new material in the text, an occasional attempt is made in this direction, such as: "It was discovered by Oerstad in 1820 . . . ," or, "Euler, writing in 1761 . . . ," but this does not occur frequently enough, and hence this might well be included in the Appendix.

Generally speaking, this book would not be purchased by the radio engineer although some of the older engineers, in some infrequent excursions outside of their specialized fields, may find helpful information, therein, not contained in the usual handbook because of its brevity.

ALOIS W. GRAF
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Chicago 3, Ill.

Elements of Television Systems by George E. Anner

Published (1951) by Prentice-Hall Inc., Publishers, 70 Fifth Ave., New York 11, N. Y. 771 pages + 14-page index + 11-page appendix + 18-page problems + xii pages. 5½ × 8½. $10.35.

The author is an assistant professor of electrical engineering at the New York University, New York 53, N. Y.

A very complete coverage of the wide range of subjects related to television is effected in this book. The material presented includes not only rather detailed information on television systems and equipments as they exist today, but also contains some features which might properly be considered as belonging to the history of the development of television. Several outmoded procedures and methods of operations are described in addition to those which are standard at present. To the reader who is looking for information on present systems, these descriptions of outmoded systems seem to have a masking effect on the information sought. To one interested in the progress mankind has made in the last few years toward the realization of the long-dreamed-of near-instantaneous transmission of pictures, the historical approach makes interesting reading.

The book is well organized and most of the subjects are clearly presented. It would appear that the writer had in mind both readers who are looking for word explanations of physical principles, and those who understand more quickly these principles through the language of mathematics. The tendency is to lean somewhat heavily toward the mathematical treatment, although the physics of the processes are very adequately presented.

The method of presentation indicates rather clearly that the book has been written primarily for physicists and engineers rather than those who are interested in the very elementary aspects of the subject.

The first chapters of the book apparently have for their objective a complete description of the manner in which picture material is converted into electrical signals which can be used to reconstruct the original picture. The theory of scanning is quite adequately treated and references are given to authoritative sources of material. Camera tubes are included for detailed explanations.

The following chapters discuss the commercial telecasting system. Synchronizing pulses are treated at length, and the relations between transmitter and receiver are rather completely explained. Throughout the book the parts played by the FCC and co-operating industries are described.

The final chapter relates to color television. The three major contending systems, CBS, CTI, and RCA, are described. This chapter might be considered less complete than the sections devoted to the black-and-white systems, and perhaps less accurate in regard to three-color mixing processes, but the fundamental principles involved in each color-television system are adequately presented.

Overall, the book is an abundant source of rather detailed information on the television system as it has developed in the United States up to the present. The reader, on finishing the book, is apt to be more firmly convinced than ever that television is the most complicated form of communication yet to be commercialized.

JOHN M. BARSTOW
Bell Telephone Laboratories, Inc.
463 West Street
New York 14, N. Y.

Basic Electron Tubes by Donovan V. Geppert

Published (1951) by McGraw-Hill Book Co., 330 W. 42 St., New York 18, N. Y. 325 pages + 4-page index + 2-page appendix. 257 figures. 6 × 9¼. $5.00.

Mr. Geppert is affiliated with the General Electric Co., Syracuse, N. Y.

This book has been written as an undergraduate text to introduce students to the basic principles of commercially available electron tubes. Microwave tubes have not been included since it is expected that the student will not have covered field theory at the time this subject is given. The reviewer feels, however, that some mention of high-frequency limitations on low-frequency triodes and tetrodes would be in order.

The chapter headings are: (1) High-vacuum and gas phototubes; (2) High-vacuum thermionic diodes; (3) High-vacuum triodes; (4) Tetrodes and pentrodes; (5) Beam power tetrodes; (6) Cathode ray tubes; (7) Glow-discharge tubes; (8) Thermionic gas diodes; (9) Thryatrons; (10) Mercury pool arc rectifiers; and (11) Ignitrons. The author introduces each of the types of tubes with illustrations pertaining to the class of the tubes. The circuit diagram for obtaining static characteristics follows, together with typical sets of static curves. A qualitative theory accounting for the observed characteristics is then followed by the mathematical equation defining the static curves. The simpler equations are derived. This approach of introducing the subject first with explanation later is novel; however, the author's handling of the subjects justifies his use of this method.

Readers may find the descriptive theory somewhat scanty, but the author has had to compress the subject into so little space that such criticism is inevitable. The book has very few technical errors, although some of the discussion on thoriated tungsten and oxide cathodes is out of date. For example, the maximum plate voltage at which thoriated tungsten filament tubes are used is no longer 4 or 5 kv. Also, the upper frequency limit on triodes is now at least 4,000 mc.

The figures are adequate and well done. Potential distributions, as obtained on a rubber sheet, are included to aid in explaining electron motion. A number of problems are presented in each chapter, and typical problems are solved in the text using both cgs and mks units.

Although the book is primarily an undergraduate text, it would be useful for the advanced engineer who wished to review the subject.

H. D. DOOLITTLE
Machlett Laboratories Inc.
Springdale, Connecticut

New Publications

Tables of the Bessel Functions of the First Kind of Orders Seventy-Nine Through One Hundred and Thirty Five, by the Staff of the Computation Laboratory of Harvard University, published by the Harvard University Press, 1951, $8.00. The tables in this volume were computed by the Automatic Sequence Controlled Calculator. This is the calculator, new in principle, which was presented in 1944 to Harvard University by the International Business Machines Corporation for operation by the Computation Laboratory.

These tables, carried to 10 decimal places, are valuable timesavers in the design departments of electrical and radio industries, in government, industrial, and business laboratories, and to scientists and mathematicians.

Mathematical Methods in Electrical Engineering by Myril B. Reed and Georgia B. Reed

Published (1951) by Harper & Bros., 49 E. 33 St., New York 16, N. Y. 332 pages+6-page index+viii pages. 91 figures. 6½×9½. $5.00.

Myril B. Reed is a Professor at the University of Illinois, Urbana, Ill.

The stated purpose of this book is to emphasize the manipulative aspects of mathematical disciplines applicable to engineering problems. The authors proceed with this by presenting a very large number of completely worked-out numerical examples. In most cases these examples do not give further insight into the methods, but rather present the routine operational aspects of a given mathematical technique. The book gives a standard treatment of the elementary phases of topics in algebra and analysis. The algebraic topics treated are: the algebra of complex numbers, linear equations and matrix algebra, partial and continued fractions, the Graeffe method for determining polynomial roots, and vector analysis. Other subjects treated are linear differential equations with an introduction to Laplace transforms, the partial differential equations of transmission lines, Bessel functions, and complex function theory. In every case only well-known preliminary aspects are examined and the treatment of the topics never deviates from the purely manipulative. Thus a reader will learn how to compute the roots of a polynomial by consulting the 21 pages of numerical examples devoted to this topic, but it is doubtful whether he will have any insight into the qualitative location of polynomial roots in the complex plane. Again the reader is given 13 pages of illustrative computation for solving linear algebraic equations, but basic considerations such as linear dependence are not presented.

The book may find some application as an undergraduate text since it has a large number of problems for class assignment; it adds little, however, to an already crowded field and cannot be heartily recommended over its numerous competitors.

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Fundamentals of Electrical Engineering by Fred H. Pumphrey

Published (1951) by Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. 662 pages+6-page index +xii pages. 460 figures. 5½×8¾.

Fred H, Pumphrey is Head Professor, Electrical Engineering, Univ. of Florida, Gainesville, Fla.

Professor Pumphrey's new book is a considerably enlarged version of his earlier work entitled "Electrical Engineering," intended as a text for students of engineering who are specializing in fields other than electrical engineering. The book is purely descriptive, with much attention given to the practical aspects of the design, construction, and use of various electrical devices. The concise and very readable style, the numerous diagrams and photographs, and the carefully worked out examples combine to produce an understandable presentation of a subject which many engineering students consider most difficult.

The discussion of fundamental concepts takes up the first four chapters of the book. Here the author introduces the concepts of current, voltage, charge, resistance, and so forth; he also discusses Kirchoff's laws and their application to the analysis of simple dc circuits. The author's treatment of these topics, although very superficial by the standards of the electrical engineer, is probably adequate for an average student of engineering.

The next 11 chapters deal principally with ac circuit analysis and machinery. The treatment of machinery is quite good, but in this reviewer's opinion, the same cannot be said of the treatment of ac-circuit analysis. In particular, the author might well have avoided introducing the difficult concept of "vector operator."

The following six chapters cover electron tubes and their applications. Included here are descriptions of various types of vacuum tubes, amplifier and oscillator circuits, cathode followers, switching circuits, multivibrators, and various electronic instruments. Magnetic amplifiers are briefly discussed in Chapter 18.

The remainder of the book is given over to a survey of the principal applications of electricity in industry. The last chapter contains a brief discussion of typical communication systems and their components.

All in all, the author has succeeded rather well in the difficult task of presenting the fundamentals of electrical engineering in a manner that is comprehensible to the non-electrical student of engineering.

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Introduction to Servomechanisms by A. Porter

Published (1951) by John Wiley & Sons, Inc. 440 Fourth Ave., New York 16, N. Y. 151 pages+2-page index+vi pages. 70 figures. 6½×4½. $1.75.

An excellent little book, in which the maximum amount of information is crammed into a minimum of space. British and American sources are quoted and very well blended into the text. This is, however, a "First Course in Servoanalysis," and not by any means an "Introduction to Servomechanisms," a much-needed book which still remains to be written.

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Ferromagnetism by Richard M. Borzoth

Published (1951) by D. Van Nostrand Co., Inc., 250 Fifth Ave., New York, N. Y. 861 pages+20-page index+12-page appendix+71-page bibliography+xvii pages. 775 figures. 6×9. $17.50.

In this book the author has made the first attempt to summarize the knowledge relating to ferromagnetism since Becker and Doring's "Ferromagnetisms" (Springer, 1939); he has succeeded admirably, and his book will serve as a standard reference for those interested in the theory, development, or utilization of ferromagnetic materials.

The book is divided into two main parts: In the first, after a brief introduction to magnetic concepts, the author takes up in detail the properties of high-permeability materials starting with iron and its alloys, and proceeding through nickel, cobalt, manganese, and their alloys. Permanent magnet materials are considered next, and the details of manufacture and processing of commercially important alloys are given special attention. The author has striven to make the book of value to readers of widely different backgrounds; for example, he begins the chapter on the magnetic properties of pure iron with a brief review of the chemistry of an iron blast furnace, and finishes it with a discussion of the diffusion rates of impurities in iron. The treatment of such extraneous topics is consistently brief and pertinent, and serves to enhance the value of the book as a reference.

The second main part of the book presents a lucid account of magnetic phenomena and theories. Here also the author has taken into consideration the varying backgrounds of the readers. The emphasis is on the physical principles involved rather than on detailed mathematical analysis. This part of the book is concluded with a brief discussion of magnetic measurements.

Among the attractive features of the book are the large number of well-chosen illustrations (almost one per page), and the chronological bibliography of some 1,700 references.

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New Publications

A new and readily understandable **Notebook on UHF Television and UHF-VHF Tunners,** generously illustrated with basic and comprehensive circuit schematics, block diagrams, and waveforms, has been announced by the Paul H. Wendel Publishing Co., Inc., of Indianapolis, Ind.

Prepared by Edward M. Noll, author of "Television for Radiomen," and "Color Television Notebook," this new publication describes the characteristics of vhf tuners with respect to gain, sensitivity, bandwidth, signal-to-noise ratio, various types of interference, and alignment. The vhf tuner section also details typical commercial tuners including RCA, Sarkes Tarzian, Standard Coil, Zenith, Stromberg-Carlson permeability tuner, Hallicrafter printed-circuit tuner, Philco tapered-line tuners, and General Instrument.

The section treating uhf television describes the nature of propagation, influence of the weather, and some of the results obtained by RCA with their experimental transmitter at Bridgeport, Conn., operating in the 529 to 535-megacycle region. Polycasting, uhf converter methods, uhf antennas, uhf converter circuits, and experimental RCA uhf tuners are also described.

The notebook contains a bibliography, a table of proposed channels for vhf-uhf television indicating frequency ranges, and a comprehensive tabulation of proposed allocations of vhf-uhf channels by cities and states. It measures 8½×11 inches, and is bound to lie flat when opened for study or reference. Copies may be obtained by sending $1.00 to the Paul H. Wendel Publishing Co., Inc., P.O. Box 1321, Indianapolis, 6, Ind.

Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

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The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1950, through January, 1951, may be obtained for 2s.8d. postage included from the *Wireless Engineer*, Dorset House, Stamford St., London, S.E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

ACOUSTICS AND AUDIO FREQUENCIES

016:534 2608

References to Contemporary Papers on Acoustics—R. T. Beyer. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 484–489; July, 1951.) Continuation of 2309 of November.

534.213.4:534.373 2609

Boundary Layer Attenuation of Higher Order Modes in Rectangular and Circular Tubes—R. E. Beatty, Jr. (*Jour. Acous. Soc. Amer.*, vol. 23, p. 481; July, 1951.) Correction to paper noted in 1045 of June.

534.231 2610

On the Acoustical Radiation of an Emitter Vibrating Freely or in a Wall of Finite Dimensions—J. Pachner. (*Jour. Acous. Soc. Amer.*, vol. 23, p. 481; July, 1951.) Correction to paper noted in 1816 of September.

534.24 2611

Sound Scattering by Solid Cylinders and Spheres—J. J. Faran, Jr. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 405–418; July, 1951.) The theory of the scattering of plane sound waves by isotropic circular cylinders and spheres is extended to take into account shear waves, which can exist as well as compression waves within solid scattering bodies.

534.321.9:534.232 2612

Generation of Ultrasonic Oscillations by means of Volume Magnetostriction—H. H. Rust. (*Z. angew. Phys.*, vol. 3, pp. 9–14; January, 1951.) Description of an experimental generator. An excitation coil is enclosed in a vessel fitted at one end with a sound-transmitting plate and filled with a suspension of carbonyl/iron powder in insulating oil. The circuit of a pulse generator of this type is shown. Qualitative tests have proved satisfactory.

534.321.9:537.228.2 2613

Magnetostrictive Ultrasonic Apparatus—H. Thiede. (*Funk u. Ton*, vol. 5, pp. 32–42; January, 1951.) Illustrated description of the construction and applications of ultrasonic transducers for the frequency range 15 to 200 kc. The electroacoustic efficiency, resonance, and attenuation factors of different forms of oscillator are discussed, and the advantages of nickel as the magnetostrictive element are reviewed. The circuit of a tube-operated drive unit providing a modulated hf excitation voltage is shown.

534.373 2614

The Absorption of Sound in Fog—Y. Rocard. (*Rev. Sci.* (Paris), vol. 89, pp. 42–43; January to March, 1951.) Measured values of the absorption of sound in fog are very different from theoretical values, particularly at high frequencies. It is tentatively suggested that the discrepancy may be due to resonant vibration of drops of moisture excited by the sound wave.

534.373:534.213.4 2615

Wall Viscosity and Heat Conduction Losses in Rigid Tubes—R. F. Lambert. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 480–481; July, 1951.) Expressions are derived for the attenuation constant and Q of rectangular and round acoustic tubes for various modes of excitation.

534.64 2616

Principle of and Apparatus for Measurement of Sound Transmission through Partitions—M. Kobrynski and A. Neyron. (*Ann. Télécommun.*, vol. 6, pp. 34–42; February, 1951.) Description of a cro installation designed to record automatically the transmission coefficient of panels 1 m square, over the frequency range 50 to 10,000 cps. The test panel is fixed between two microphones at one end of a sealed echo-free chamber, and a uniform sound pressure is applied to the external face of the panel. Voltage proportional to the logarithm of the instantaneous frequency is applied to the timebase plates of the cro, while voltage proportional to the decibel difference at the two microphones, obtained by use of logarithmic-sensitivity amplifiers, is applied to the deflecting plates.

534.75 2617

The Frequency Selectivity of the Ear as determined by Masking Experiments—S. de Walden. (*Jour. Acous. Soc. Amer.*, vol. 23, p. 481; July, 1951.) Comment on 2692 of 1950.

534.75:621.39.001.11 2618

Information and the Human Ear—H. Jacobson. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 463–471; July, 1951.) Calculations of the capacity of the human ear to handle information are made by computing the number of sound patterns per second that can be discriminated, and applying the Shannon information theory. A maximum of 10^4 bits per second is found. This is compared with corresponding values for other sound channels, and with the observed rate of perception of information from speech and music. A capacity of 5×10^4 bits per second is necessary for high fidelity. The brain is able to use <1 per cent of the information transmitted by the ear.

534.78 2619

The Influence of Interaural Phase on Masked Thresholds. I. The Role of Interaural Time-Deviation—F. A. Webster. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 452–462; July, 1951.) The masking of a tone or narrow-band noise, the signal, by wide-band noise, is discussed with particular reference to the interaural phase differences for signal and noise, respectively. Audibility is best when the interaural phase difference for the signal is 180°, and that for the masking noise is zero. Experimental results are discussed in terms of the interaural phase- and time-deviations produced by the superposition of the signal on the noise.

534.78 2620

A Phoneme Detector—C. P. Smith. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 446–451; July, 1951.) Description of a device in which an incoming speech signal is compared with a set of stored energy-distribution reference patterns, and the best fit among the reference patterns is selected. Contiguous band filters covering the range 100 cps to 7 kc are used to dissect the incoming signal, and special arrangements are incorporated to provide improved selectivity and discrimination against noise.

534.851 2621

Intermodulation Distortion in Gramophone Pickups—S. Kelly. (*Wireless World*, vol. 57, pp. 256–259; July, 1951.) A special test record is used having negligible intermodulation components. The frequencies are 60 cps and 2,000 cps on one side, and 400 cps and 4,000 cps on the other. The output from a pickup playing this record is observed either on an intermodulation test set, or visually on a cro.

534.861:621.396.61 2622

Justification for raising the Standard of Broadcast Transmissions—M. Beurtheret. (*Onde élect.*, vol. 31, pp. 184–187; April, 1951.) Improvements in the quality of broadcast transmissions can improve reception for a large number of listeners. Conventionally accepted criteria of quality do not take adequate account of the worst faults, viz., frequency distortion due to intermodulation, and transient distortion. Use of a high degree of negative feedback in the transmitter is recommended to improve quality. Perfect linearity of the af

amplitude/frequency characteristic of the transmitter is essential only in the range 50 to 2,500 cps; the production of high-quality broadcast transmitters is simplified if it is not attempted to extend the linear range unnecessarily.

621.395.61+534.321.9 2623
On the Possibility of a True Mechanical Transformer—Y. Rocard. (*Rev. Sci.* (Paris), vol. 88, pp. 236–238; October to December, 1950.) A rod, the cross section of which varies exponentially, has the properties of an impedance transformer for longitudinal, transverse, and torsional vibrations. Practical applications of the device in transducers, etc., are described.

621.395.616:534.612.4 2624
Condenser Microphone Sensitivity Measurement by Reactance Tube Null Method—H. E. von Gierke and W. W. von Wittern. (PROC. I.R.E., vol. 39, pp. 633–635; June, 1951.) The capacitance variations produced by energizing voltages in the frequency range 20 cps to 200 kc, are balanced against corresponding capacitance changes produced in a calibrated reactance-tube circuit. The capacitance variations are arranged to modulate the amplitude of a 3-mc carrier. Balance is observed by means of a cro to which the demodulated signal is applied.

621.395.623 2625
The Transmission Factor and Distortion Factor of an Electrodynamic Sound Receiver—G. Haar. (*Funk u. Ton*, vol. 5, pp. 17–26; January, 1951.) Description of measurement circuits, and procedure for determination of the characteristics, of a headphone designed for acoustic tests in the range 50 to 5,000 cps. Its advantages over a loudspeaker are outlined. Its low inherent distortion factor makes it especially useful for investigation of nonlinear distortion in an af system.

621.395.623.7 2626
Loudspeaker Diaphragm Control—J. Moir. (*Wireless World*, vol. 57, pp. 252–255; July, 1951.) Loudspeakers of current designs are critically damped by an amplifier having an output impedance >10 to 20 per cent of the dc voice-coil resistance. The use of loud speakers in small rooms prevents any advantge being obtained from over-critical damping. The use of an exponential horn is recommended to increase damping of the cone oscillation at high frequencies, and to flatten the voice-coil impedance curve.

621.395.623.7:534.13 2627
Growth of Subharmonic Oscillations—W. J. Cunningham. (*Jour. Acous. Soc. Amer.*, vol. 23, pp. 418–422; July, 1951.) The conditions necessary for the excitation in a resonant system of oscillations at half the driving frequency are discussed. An experiment is described, using a suitably energized lc tuned circuit. The mode of production of subharmonic vibrations in a direct-radiator loudspeaker is also discussed, and experimental data are given.

621.395.623.7:534.231 2628
Sound-Field Regulator—P. Riety. (*Ann. Télécommun.*, vol. 6, pp. 43–48; February, 1951.) Description of a system providing a sound field of constant strength over the range 20 cps to 15 kc. The input to the loudspeaker amplifier is fed through a regulating circuit to which is applied a control voltage corresponding to the emf developed by a "pilot" microphone in the sound field of the loudspeaker, so that the input to the latter is inversely proportional to its acoustic efficiency. The time lag of the regulation is discussed. Amplification range is >30 db.

621.395.625.3 2629
A Professional Magnetic-Recording System for Use with 35-, 17½- and 16-mm Films—G. R. Crane, J. G. Frayne, and E. W. Templin. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 295–309; discussion, p. 309; March, 1951.) Description of portable equipment for producing a high-quality sound track for motion pictures.

621.395.625.3 2630
A.C. Magnetic Erase Heads—M. Rettinger. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 407–410; April, 1951.) Various ring-shaped heads for erasing magnetic records are compared. Measurements were made of the degree of erasure obtained, and the temperature rise of the head as the 70-kc erase current was varied. Best results were obtained with two heads in cascade.

621.395.625.3 2631
A German Magnetic Sound Recording System in Motion Pictures—M. Ulner. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 411–422; April, 1951.) For economy, magnetic tape (6.5 mm) is used for all original sound records in German film studios, film being used only in re-recording on the final negative. A description is given of the magnetic recorder and play-back amplifier, and of the method of synchronization with the picture.

621.396.645.029.3 2632
Extended Class-A Audio—Sterling. (*See* 2680.)

ANTENNAS AND TRANSMISSION LINES

621.315.212 2633
The Behaviour of Curved Uniform Lines at High Frequencies—H. H. Meinke. (*Arch. elekt. Übertragung*, vol. 5, pp. 106–112; March, 1951.) The case of a line bent into an arc of a circle is considered. An equation is derived, giving the change of characteristic impedance introduced for a line of arbitrary cross section. A formula giving a very close approximation is derived for the coaxial line, and some other cross sections are discussed. The effective length of the line is given by the circumference of a circle whose radius is equal to the mean radius of curvature as particularly defined. For the sake of simplicity, the discussion is restricted to cases in which axial field components may be neglected.

621.315.212:621.3.09 2634
The Effect of Connectors on the Properties of a Cable—M. Cotte. (*Câbles & Trans.* (Paris), vol. 5, pp. 84–87; January, 1951.) The effect on the propagation characteristics of discontinuities introduced by connectors between lengths of cable, is discussed. The levels of parasitic echo signals so introduced are calculated for transients and for steady-state conditions. Phase distortion due to differences in group velocities is estimated. To keep these distortion effects within given limits, the product of the reflection coefficient between a cable length and a connector, multiplied by the length of the connector, must be smaller than a predetermined value. In practice, with typical cables and connectors, it is found that echo-effect distortion is more important than phase distortion. The requirements for good transmission are met by correctly designing the connectors.

621.315.212:621.392.43 2635
Coaxial-Stub Filter—J. A. Craig. (*Electronics*, vol. 24, pp. 132, 134; June, 1951.) Describes the use of correcting stubs for coaxial transmission lines.

621.392.09 2636
Single-Conductor Surface-Wave Transmission Lines—G. Goubau. (PROC. I.R.E., vol. 39, pp. 619–624; June, 1951.) General information and design data relating particularly to the dielectric-coated conductor. See also 281 of March and 812 of April.

621.392.21 2637
Note on the Variations of Phase Velocity in Continuously-Wound Delay Lines at High Frequencies—I. A. D. Lewis. (*Proc. IEE*, vol. 98, pp. 312–314; July, 1951.) "The effect of the self-capacitance of the winding on the velocity and on the characteristic impedance is here determined by a simple method. A direct treatment is given of the decrease in the inductance per unit length which occurs when the wavelength along the coil is not very large compared with the winding diameter. The two effects have opposite influences on the velocity, and a fair degree of cancellation can be attained if a certain relationship between the parameters is satisfied."

621.392.26† 2638
On the Representation of the Electric and Magnetic Fields produced by Currents and Discontinuities in Wave Guides—N. Marcuvitz and J. Schwinger. (*Jour. Appl. Phys.*, vol. 22, pp. 806–819; June, 1951.) The calculation of the fields, produced by prescribed and induced currents at a discontinuity, is treated by representing the fields in terms of a complete set of vector modes characteristic of the possible transverse field distributions in the waveguide cross section. This representation transforms the field problem into one-dimensional modal problems of conventional transmission-line form. The eigenvalue problem of finding the characteristic modes is discussed in detail for the case of a uniform guide with perfectly conducting walls. A typical modal analysis and synthesis are presented for infinite and semi-infinite waveguides of arbitrary cross section.

621.392.26†:621.39.09 2639
The Significance of the Transmission-Line Equations and Characteristic Impedance for Waves of Arbitrary Type in Cylindrical Lines—F. Borgnis. (*Arch. elekt. Übertragung*, vol. 5, pp. 181–189; April, 1951.) The familiar transmission-line equations expressing the spatial distribution of current and voltage along a Lecher line, apply also to the propagation of an arbitrary electric wave in a cylindrical line (e.g., a waveguide) provided it is possible to excite a single electric or magnetic mode in the line. The special interpretation to be attached to the concepts "current," "voltage," and "characteristic impedance" in this case, is discussed.

621.392.26†:621.39.09 2640
The Velocity of Propagation of H_{on} Waves in a Multilayer Waveguide—N. N. Malov. (*Zh. Tech. Fiz.*, vol. 20, pp. 1509–1510; December, 1950.) A discussion of the possibility of using waveguides filled with two or three layers of dielectrics as phase changers, with comments on a paper by Fox (1255 of 1948).

621.392.26†:621.396.67 2641
Application of Array Theory to Nonresonant Slotted Waveguides—J. B. Tricaud. (*Onde élect.*, vol. 31, pp. 122–132 and 188–200; April, 1951.) The directive properties of halfwave dipole arrays, fed by a waveguide, are compared with those of a slotted guide. The slotted guide is discussed in detail as a particular class of linear array. Schelkunoff's space-factor theory is developed to give the amplitude-distribution function. Approximate sinusoidal solutions are worked out, and the usefulness of the method, permitting the expression of results as asymptotes, is emphasized with examples. The theory is applied to consideration of the radiation from a single slot, the matching of impedance along a slotted guide, and the relation between amplitude distribution and load. The characteristics of a typical low-radiating-angle radar antenna, using a nonresonant slotted guide, are given.

621.396.67 2642
U.R.S.I.—I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951.— (PROC. I.R.E., vol. 39, pp. 716–720; June, 1951.) Summaries are given of the following papers:

15—Low-Frequency Antennas—P. S. Carter.
16—Antenna Systems for Radio Direction Finding—E. C. Jordan.
17—Electrically Small Antennas and the Low-Frequency Airborne Antenna Problem—J. T. Bolljahn.
18—Antennas in Conducting Media—R. K. Moore.
29—On the Theory of Antenna Beam-Shaping—A. S. Dunbar.
30—Beam Shaping in Doubly Curved Reflector Systems employing Quasi-Point Sources—A. E. Marston.
31—Lack of Uniqueness in Antenna Pattern Synthesis Methods and the Related Energy Storage Considerations—T. T. Taylor.
32—Feed Problems in Broad-Band Antenna Arrays—W. R. LePage and R. F. Gates.
33—Second-Order Beams of Slotted Waveguide Arrays—H. Gruenberg.
42—Aperture Phase Errors in Microwave Optics—K. S. Kelleher.
43—Review of Spherical Reflector Research at A.F.C.R.L.—J. E. Walsh.
44—Review of Recent Metal Lens Research at A.F.C.R.L.—J. Ruze.

621.396.67 2643

Wrotham Aerial System: Part 2—The Main Transmission Line and the A.M./F.M. Combining Filter—C. Gillam. (*Wireless World*, vol. 57, pp. 279–282; July, 1951.) The transmission line which conveys rf power to the multiple-slot radiator and distribution system (see Part 1: 2340 of November) is described. FM and AM transmissions can be radiated simultaneously from the single antenna system.

621.396.67 2644

Improved Anti-Fade Transmitting Aerial—H. Brückmann. (*Funk u. Ton*, vol. 5, pp. 5–16; January, 1951.) Full paper of which a shorter version in English was abstracted in 1863 of 1950.

621.396.67 2645

Impedance Characteristics of Thick Cylinders—S. Zisler. (*Onde élect.*, vol. 31, pp. 133–143; March, 1951.) The input impedance of cylindrical antennas, and in particular of thick cylinders, is calculated by an extension of two-wire transmission line theory. The equivalent coaxial line is assumed to have damping resistance and reactance uniformly distributed along its length, to account for power loss due to radiation from the antenna, and to provide the same current distribution in the line as is found in the antenna. Results are quoted, with curves and diagrams, for cylindrical $\lambda/4$ and $\lambda/2$ antennas for a length-to-diameter ratio between 2 and 50.

621.396.67 2646

Aperiodic Aerials: Use with Vertical-Incidence Ionospheric Recorders—R. Bailey. (*Wireless Eng.*, vol. 28, pp. 208–214; July, 1951.) An analysis is made of the performance of several types of simple resistance-terminated traveling-wave antennas, of practical height and shape, for transmission and reception in a vertical direction above a perfectly flat earth. The results are used to find the conditions for best signal-to-interference ratio for ionospheric echoes between about 0.5 and 20 mc, using the minimum number of antennas to cover the whole range. The results may also have application to short-distance sky-wave radio communication.

621.396.67.014.1 2647

Current Distributions on Helical Antennas—J. A. Marsh. (Proc. I.R.E., vol. 39, pp. 668–675; June, 1951.) Measurements were made over the frequency range 600 to 1,700 mc on two uniform circular helices, of diameter 8.61 cm, pitch angle 12.6°, and different lengths, using a sampling probe. The distributions of current amplitude and phase are shown graphically, and a satisfactory interpretation is given in terms of three traveling-wave modes. The relative phase velocities in the modes are deduced. When the T_1 mode predominates, there is good agreement between measured and calculated velocities and the value required for optimum end-fire directivity.

621.396.671+621.396.11 2648

Application of the Compensation Theorem to Certain Radiation and Propagation Problems—G. D. Monteath. (*Proc. IEE*, vol. 98, pp. 319–320; July, 1951.) Digest of IEE monograph. The compensation theorem is extended to deal with a continuous system in which a solution of Maxwell's equations must satisfy certain boundary conditions. In particular, the change in mutual impedance between two antennas is considered when changes are made to other parts of the system, e.g., the surface of the earth. The result is expressed in terms of the change in surface impedance.

621.396.671 2649

The Patterns of Antennas Located near Cylinders of Elliptical Cross Section—G. Sinclair. (Proc. I.R.E., vol. 39, pp. 660–668; June, 1951.) The patterns of small dipole and loop antennas mounted on or near a perfectly conducting cylinder of elliptical cross section, are calculated by determining the open-circuit terminal voltages of the antennas when receiving plane waves. The antennas are assumed to be such that they cause negligible distortion of the field when they are open circuited, thus reducing the problem to that of calculating the diffraction of a plane wave around the cylinder. The results have applications in the design of aircraft antennas and slotted-cylinder antennas.

621.396.671:778.3 2650

Photo Radiation Patterns—G. W. Goebel. (*Electronics*, vol. 24, p. 89; May, 1951.) A simple and economical method is described for exhibiting two-dimensional patterns of two or more interfering radiators of the same frequency and polarization.

621.396.676.029.6 2651

A Very-High-Frequency—Ultra-High-Frequency Tail-Cap Antenna—L. E. Raburn. (Proc. I.R.E., vol. 39, pp. 656–659; June, 1951.) An account of the development of an omnidirectional zero-drag aircraft antenna for vertical polarization. By insulating the vertical stabilizer from the remainder of the tail structure, a suitable radiator was obtained, covering the frequency band 100 to 400 mc. The principal radiation patterns are illustrated, and some details of mechanical design are included.

621.396.677 2652

Wide-Angle Metal-Plate Optics—J. Ruze. (Proc. I.R.E., vol. 39, p. 697; June, 1951.) Correction to paper abstracted in 1345 of 1950.

621.396.677 2653

Factors affecting Performance of Directional Antennas—A. E. Cullum, Jr. (*Broadcast News*, no. 63, pp. 43–51; March/April, 1951.) The horizontal and vertical radiation patterns for various phase and space relations of a two-element antenna show the distribution of the radiation between sky and ground waves. The influence of the shape and bonding of the towers, guy layout, and insulation and ground screens on the radiation pattern, is considered. Methods of sampling the radiated fields are given.

621.396.677.3 2654

On the Response of a Directive Antenna to Incoherent Radiation—F. W. Schott. (Proc. I.R.E., vol. 39, pp. 677–680; June, 1951.) A general expression is derived for the power gain of a directive antenna over a nondirective antenna, when receiving radiation comprising components with various directions of arrival and random phases. The usual method of expressing signal strength in db relative to a particular μv/m level may give rise to error in this case; only the received power can be stated. Results obtained by measurement with parabolic antennas at 9.375 kmc show that for widely scattered radiation the antenna aperture has little effect on received power.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.015.7 2655

Improved Pulse Stretcher—J. F. Craib. (*Electronics*, vol. 24, pp. 129–131; June, 1951.) A delay line, charged by crystal rectifiers in parallel, is used to stretch pulses up to 25 times their original length. The effects produced by superposing pulses within the stretch time are discussed. Design equations are presented.

621.316.729 2656

Synchronization of Relaxation Oscillations at Fundamental and Subharmonic Frequencies of an Applied Electromotive Force: Part 4—V. V. Vitkevich. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1245–1256; October, 1950.) In continuation of previous papers (see *Elektrosvyaz*, no. 11, 1940; *Zh. Tekh. Fiz.*, vol. 14, nos. 1/2, 1944; and vol. 15, no. 11, 1945), a general case is considered in which several electromotive forces are applied to the oscillator and, in addition, the critical voltage value of the nonlinear element is affected by these forces. Formulas are derived for determining the amplitudes and synchronization bandwidths at the fundamental and subharmonic frequencies of the complex applied emf, and a general theory of the synchronization of asymmetrical and symmetrical oscillators is presented. A geometrical interpretation of the conclusions is given.

621.316.8 2657

The Problem of a Non-ohmic Resistor in Series with an Impedance—E. B. Moullin. (*Proc. IEE*, vol. 98, pp. 87–96; March, 1951.) An experimental determination of the rms voltage required to maintain a given current through a silicon-carbide resistor in series with an ohmic resistor or a reactor. An appendix shows how the observed results can be predicted from the static characteristic by simple algebraic methods. The observed waveforms are also discussed.

621.318.4.042.13 2658

Cylindrical-Coil Theory applied to Calculation of Reluctance or Resistance between the End of a Straight Core and Infinity—P. M. Prache and R. Cazenave. (*Câbles & Trans.* (Paris), vol. 5, pp. 60–67; January, 1951.) A theoretical study is made of the reluctance along a tube of force through an air-cored cylindrical coil. An expression for the reluctance between the end of the coil and infinity is obtained as the difference between the total reluctance of the tube of force and that of its part inside the coil. Its value is nearly independent of the flux distribution within the winding. The expression is useful in the calculation of discontinuous magnetic circuits. The results obtained for reluctance may be translated into terms of resistance for estimating the value of resistance between the end of a cylindrical body and infinity.

621.318.42 2659

Design of Input (Regulation Control) Chokes—N. H. Crowhurst. (*Electronic Eng.* (London), vol. 23, pp. 179–181; May, 1951.) A design chart is presented for determining the optimum specification for a choke to cover a given range of current and output voltage. It is intended to be used in conjunction with the charts noted in 1096 of June.

621.318.572 2660

The Cascaded Binary Counter with Feedback—G. F. Montgomery. (*Jour. Appl. Phys.*, vol. 22, pp. 780–782; June, 1951.) A cascade of binary counters having arbitrary feedback arrangements introducing additional pulses, is analyzed. For a given count, or scale, a feedback arrangement requiring a minimum number of connections can be found.

621.318.572:621.385.3:546.289 2661
Some Transistor Trigger Circuits—P. M. Schultheiss and H. J. Reich. (PROC. I.R.E., vol. 39, pp. 627–632; June, 1951.) A survey of possibilities. Each of five circuits shown has operated successfully with at least one transistor. Difficulties encountered in reproducing results with other transistors or altered parameters are discussed.

621.385.3:546.289 2662
Duality, a New Approach to Transistor Circuit Design—R. L. Wallace, Jr. (PROC. I.R.E., vol. 39, p. 702; June, 1951.) Outline of principles applied. See 2369 of November.

621.385.3:621.385.5 2663
Valve Operating Conditions—(*Wireless Eng.*, vol. 28, pp. 195–196; July, 1951.) A triode with capacitive load and without feedback, may be cut off by a negative-going input voltage which can be amplified when no capacitance is present. The operation of triodes and pentodes under these conditions is discussed, and the case of an inductively-loaded pentode is also considered.

621.392 2664
A Network Theorem and its Application—F. W. Bubb, Jr. (PROC. I.R.E., vol. 39, pp. 685–688; June, 1951.) The theorem here proved is useful in analyzing the response of an hf circuit to an am signal by relating it to the response of an equivalent lf circuit to the signal envelope. The cases of a single-tuned circuit and a two-stage stagger-tuned amplifier are calculated as examples.

621.392.5 2665
Generalized Impedance Circle Diagrams in the Analysis of Coupled Networks—C. Ghosh. (*Indian Jour. Phys.*, vol. 24, pp. 223–231; May, 1950.) A practical method of developing circle diagrams for a representative "T" network is described for cases in which the circuit parameters vary.

621.392.5 2666
Generalized Representation of a Valve Circuit by an Iterative Matrix—U. Kirschner. (*Arch. elekt. Übertragung*, vol. 5, pp. 190–196; April, 1951.) The circuit is considered as an active quadripole, and matrix methods are developed, enabling its performance to be predicted. In illustration, the calculation is carried out for four different pentode circuits. See also 837 of May.

621.392.5 2667
Constant-Resistance Networks of the Linear Varying-Parameter Type—L. A. Zadeh. (PROC. I.R.E., vol. 39, pp. 688–691; June, 1951.) Explicit expressions are derived for the transfer function of such networks. See 834 of May.

621.392.5 2668
Initial Conditions in Linear Varying-Parameter Systems—L. A. Zadeh. (*Jour. Appl. Phys.*, vol. 22, pp. 782–786; June, 1951.) The response of the initially excited system to a given input is considered. Mathematically, the problem involves the solution of a linear differential equation, with time-dependent coefficients, subject to prescribed initial conditions. These conditions may be satisfied by superposing upon the given input a linear combination of delta functions, and treating the system as if it were initially at rest. Using the concept of a system function, a simple general expression for the response is developed. The result is similar in form to that obtained by the use of conventional Laplace transformation techniques in the case of a linear differential equation with constant coefficients.

621.392.52 2669
Input Admittance, Output Admittance and Voltage Transformation at the Centre of the Pass Band in Variable Three-Stage Filters—W. Pfost. (*Arch. elekt. Übertragung*, vol. 5, pp. 77–80; February, 1951.) General theory for the electrical design and construction of these filters was given in 843 of 1950. Formulas are now derived for the input and output admittances, and for the voltage transformation ratio at the center of the pass band. The values found are shown graphically and discussed. As required by the theory, the amplification is independent of direction of operation, and is nearly independent of bandwidth.

621.392.52 2670
The Double-T RC Filter—J. Thouzery. (*Radio franç.*, nos. 1–4, pp. 6–11, 17–20, 20–22 and 19–22; January to April, 1951.) The theory of the double-T filter is discussed at length, after a preface on tensor analysis. The relation between the ratio volts-input to volts-output, and the constants of the network, i.e., the transfer equation, is investigated for the general case and for practical parameters. Expressions are derived for the resonance frequency of the network for both general and particular cases, and frequency response curves are shown. Practical examples are discussed to illustrate applications of the theory.

621.392.6 2671
Representation of a Network or Transmission System by a Number of Superposed Balanced Circuits—L. J. Collet. (*Câbles & Trans.* (Paris), vol. 5, pp. 3–24; January, 1951.) Following on an earlier paper on superposed circuits (592 of April), a generalized treatment is given of the problem of balanced ac circuits. In any network, those circuits which can be defined by real coefficients are designated as real. In this sense it is shown that a network having a number of terminals exceeding by n the number of its component loops, can always be resolved into n real and mutually balanced circuits. Hence, a network including two sets of terminals each characterized by the same number n, can generally be resolved into n electrically independent quadripoles. Thus a transmission line constituted by n wires and the ground can be resolved into n balanced circuits.

621.396.6:061.4 2672
1951 Components Exhibition, Paris—J. Rousseau. (*T.S.F. pour Tous*, vol. 27, pp. 100–102 and 162–167; March and April, 1951.) Short illustrated review of exhibits. For other accounts see *Radio prof.* (Paris), vol. 20, pp. 16–19, February, 1951; *Télévision*, no. 12, pp. 75–78, March/April, 1951; *Radio franç.*, no. 2, pp. 13–15, February, 1951, and *Toute la Radio*, no. 154, pp. 99–107, March/April, 1951.

621.396.611.1 2673
The Influence of Initial Phase Angle on the Excitation of Subharmonic Oscillations in a Nonlinear Circuit—G. J. Elias, S. Duinker, and Tan Soen Hong. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 69–84; March, 1951.) Report of an experimental investigation of oscillations excited in a circuit comprising capacitor and iron-cored inductor by a sinusoidal-voltage input. Graphs are used to show the initial values of phase and amplitude for which relaxation and subharmonic oscillations occur, for various values of capacitance. The effect on subharmonic response of additional resistance is considered. The phase-angle control-switch circuit used is described in an appendix.

621.396.611.3 2674
The Pull-In Effect in Coupled Circuits—W. Herzog. (*Arch. elekt. Übertragung*, vol. 5, pp. 81–84; February, 1951.) To provide a physical picture of the pull-in effect, the simple case is considered of a bridge oscillator with two resonator circuits in parallel, the capacitance in one circuit being variable. The reactances of the two circuits are plotted on the same graph against frequency, and the dependence of the oscillation on the difference between the two reactances is demonstrated.

621.396.615 2675
Oscillators—W. Herzog. (*Arch. elekt. Übertragung*, vol. 5, pp. 169–180; April, 1951.) A comparative survey is given of the most useful oscillator circuits. Formulas determining amplitudes and frequencies are established.

621.396.619.13.018.78† 2676
Distortion in Linear Passive Networks—L. Riebman. (PROC. I.R.E., vol. 39, pp. 692–697; June, 1951.) A development of the theory of distortion in an FM system, based on a series solution of the superposition integral, provides a method of calculating the distortion produced by practical receiver circuits when the circuit transfer function is known in pole-zero form.

621.396.622.63 2677
The Diode Rectifier—D. Geist. (*Z. angew. Phys.*, vol. 3, pp. 32–35; January, 1951.) A theoretical treatment of the crystal-diode-capacitor circuit. The current-voltage characteristic is taken as linear, with different slopes in the forward and reverse regions, a finite value of resistance being assumed in the reverse region. The time constant, efficiency, etc., can be calculated from the formulas derived. In the special case of infinitely high reverse resistance, the formulas apply also to the tube rectifier.

621.396.645.018.422† 2678
Simplified Q Multiplier—H. E. Harris. (*Electronics*, vol. 24, pp. 130–132, 134; May, 1951.) A narrow-band amplifier incorporating a negative-resistance circuit and having high stability and ease of control, is described. The parallel-tuned circuit whose Q is to be increased, is connected to the grid of a cathode follower. The cathode is connected via a variable resistance to a tap on the tuned circuit. A stable Q of 30,000 can be obtained.

621.396.645.018.424† 2679
Notes on Wide-Band Amplifiers—L. Bernardi. (*Poste e Telecomun.*, vol. 18, pp. 261–274; July, 1950.) Practical design data for amplifiers used in carrier-frequency telephony or television are presented. Phase shift and amplification loss in voltage amplifiers at low and high frequencies are considered, and suitable compensating networks discussed. At hf, various two- and four-terminal networks are available. Cathode coupling of power amplifiers to coaxial cable is considered. A worked example illustrates the method.

621.396.645.029.3 2680
Extended Class-A Audio—H. T. Sterling. (*Electronics*, vol. 24, pp. 101–103; May, 1951.) Description of a push-pull af power amplifier, using a triode and tetrode connected in parallel in each half, and delivering nearly 50 w from four Type 807 tubes. At low levels, the tetrodes are cut off, and class-A triode operation is obtained with low distortion and power consumption. At high levels, the tetrodes conduct and deliver the full output required.

621.396.645.029.3 2681
Amplifier of Variable Output Impedance—R. Yorke and K. R. McLachlan. (*Wireless Eng.*, vol. 28, pp. 222–225; July, 1951.) Positive and negative feedback are used to provide an output impedance variable from -10 to $+20\Omega$. The amplifier characteristics were investigated experimentally, and the principal results are outlined.

621.396.645.215 2682
Improvement of the Frequency Response of Output Transformers by use of Filter Coupling—R. Seidelbach. (*Funk u. Ton*, vol. 5, pp. 27–31; January, 1951.) The leakage inductance of the transformer is incorporated in a π-type filter, and a selective L-type network is coupled directly to this. The system provides a high-frequency cutoff at a frequency below 25 kc, and is useful in an anode-modulation circuit in which frequencies of 25 to 60 kc give

rise to distortion. Frequency attenuation figures are tabulated for a typical set of component values.

621.396.645.3 2683
Maximum Permissible Value of Grid-Leak Resistance—O. Schmid. (*Arch. elekt. Übertragung*, vol. 5, pp. 85–88; February, 1951.) The value of the grid-leak resistance for an amplifier tube is required to be smaller the nearer the tube is worked to the zero-grid-voltage point, and the longer the grid remains at low values of negative potential. Hence, care is needed in fixing the value of this resistance for dc, af, and pulse amplifiers, in order to avoid nonlinear distortion. Where the grid voltage is changing rapidly, there is no danger of distortion if the value of the grid-leak resistance is fixed according to the mean values of grid current and grid voltage.

621.396.645.35 2684
D.C. Amplifiers—J. Schérer. (*Toute la Radio*, no. 154, pp. 93–96; March/April, 1951.) Traces the evolution of dc amplifiers, and indicates modern practice.

GENERAL PHYSICS

537.311.5+538.569.4 2685
U.R.S.I.-I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951—(Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) Summaries are given of the following papers:

8—Validity and Limitations of the Van Vleck-Weisskopf Equation for Atmospheric Microwave Absorption—T. F. Rogers.

41—Current Distributions on Large Reflecting Cylinders—H. J. Riblet.

537.523.3+537.525.3 2686
Starting Potentials of Positive and Negative Coronas with Coaxial Geometry in Pure N_2, Pure O_2, and Various Mixtures at Pressures from Atmospheric to 27 mm—C. G. Miller and L. B. Loeb. (*Jour. Appl. Phys.*, vol. 22, pp. 740–741; June, 1951.)

537.525.6:538.56]:621.396.615.142 2687
Electron Plasma Oscillations—Wehner. (*See* 2875.)

537.528:621.315.61 2688
The Formation of Conducting Bridges in Suspensions of Conductors and Semiconductors in Dielectrics: Part 2—L. G. Gindin, L. M. Moroz, I. N. Putilova, and Ya. I. Frenkel. (*Zh. Tekh. Fiz.*, vol. 21, pp. 143–148; February, 1951.) The behavior of 0.1 per cent suspensions of Al in benzene under strong electric fields was investigated, and, in particular, the formation of conducting "bridges" made up of Al particles between the electrodes. The effect of various factors on the formation of these bridges is discussed.

538.221 2689
Ferromagnetism: Magnetization Curves—E. C. Stoner. (*Rep. Progr. Phys.*, vol. 13, pp. 83–179; bibliography, pp. 180–183; 1950.) In this report, which is complementary to that abstracted in 3395 of 1948, an account is given of experimental and theoretical work over a period of about 16 years, on the behavior of ferromagnetic materials in low and medium fields. The complex of behavior represented by the magnetization curves of ferromagnetics is regarded as arising from small perturbations. The investigations selected for consideration are those providing quantitative information about these elementary processes, or exemplifying general methods of attacking the problems or illustrating general principles.

538.3:530.145 2690
The Reciprocity Theory of Electrodynamics—H. S. Green and K. C. Cheng. (*Proc. Roy. Soc. Edinb. A*, vol. 63, part 2, pp. 105–138; 1949/1950.) Application of the principle of reciprocity to problems of classical and quantum electrodynamics. The first step is the formulation of a reciprocally invariant Lagrangian function for a system of electrons in interaction with the em field. A study of the unaccelerated motion of an electron is extended to the case of arbitrary motion. The Hamiltonian energy of electron and field is determined, and this makes it possible to express the theory in a quantum form which avoids the usual divergence difficulties.

538.311:513.647.1:621.318.423 2691
Waves Guided by Helical Circuits—É. Roubine. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1748–1750; May 7, 1951.) A more general analysis than that presented in 1350 of July, applicable to any circuit whose limiting surface is generated by the helical motion of a curve. The electric field may be expressed in terms of a function Φ, which is the solution of an equation bearing to the Goldstein equation the same relation as the wave equation bears to the Laplace equation. The theory is applicable to (a) delay lines, (b) traveling-wave tubes, and (c) helical antennas.

538.56:535.13 2692
On the Nonspecular Reflection of Electromagnetic Waves—V. Twersky. (*Jour. Appl. Phys.*, vol. 22, pp. 825–835; June, 1951.) The nonspecular reflection of plane electromagnetic waves of arbitrary polarization by perfectly conducting surfaces, composed of either semicylindrical or hemispherical bosses on an infinite plane, is analyzed. Solutions for the problem of the single boss are given and extended to cover patterns of bosses. The results for the various cases are compared, and expressions are obtained for the ratios of the components of the reflected wave.

538.56:535.42 2693
Diffraction of Centimetre Electromagnetic Waves by Metal and Dielectric Disks—H. Severin and W. V. Baeckmann. (*Z. angew. Phys.*, vol. 3, pp. 22–28; January, 1951.) The field distribution in the axial region of a metal disk was investigated experimentally. Methods using a fixed disk and a movable disk led to similar results. The latter method, applied in the case of a dielectric disk, showed that the diffracted wave differs from that for a metal disk only by a constant factor which is identical with the optical reflection coefficient.

538.56:535.42 2694
Theory of the Diffraction of Electromagnetic Waves—H. Severin. (*Z. Phys.*, vol. 129, pp. 426–439; April 2, 1951.) Green's tensors are used to derive boundary-value formulas for electromagnetic diffraction, by means of which the field in the space can be calculated from the tangential components of the electric or magnetic field-strength over the boundary.

538.566 2695
Huyghens' Principle for an Electromagnetic Wave—R. de Possel and C. Pouget-Michel. (*Compt. Rend. Sci.* (Paris), vol. 232, pp. 1819–1821; May 16, 1951.) Huyghens' principle is expressed in terms of electric and magnetic doublets similar to those used by Larmor for the general solution of Maxwell's equations in a vacuum. Love's potentials are introduced. The method of deducing from the derived expression the classical formulas involving charges and currents, is indicated.

538.566 2696
Wave Packets, the Poynting Vector, and Energy Flow: Part 2—Group Propagation through Dissipative Isotropic Media—C. O. Hines. (*Jour. Geophys. Res.*, vol. 56, pp. 197–206; June, 1951.) A theoretical paper. For pulses propagated in infinite media or through slabs having appreciable absorption, the speed of transmission to be expected is $c/(\mathrm{d}kn_1/\mathrm{d}k)$, where n_1 is the real part of the refractive index at frequency $kc/2\pi$. Part 1: 1881 of September.

538.566 2697
Wave Packets, the Poynting Vector, and Energy Flow: Part 3—Packet Propagation through Dissipative Anisotropic Media—C. O. Hines. (*Jour. Geophys. Res.*, vol. 56, pp. 207–220; June, 1951.) "Formulas are developed giving the velocity of packet propagation in dissipative anisotropic media for both homogeneous and inhomogeneous waves." Part 2: above.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72+523.85]:621.396.822 2698
Radio Astronomy—M. Ryle. (*Rep. Progr. Phys.*, vol. 13, pp. 184–245; bibliography, pp. 245–246; 1950.) A survey, complementary to those of Hey (91 of 1950) and Pawsey (104 of February). Details of experimental observations are dealt with relatively briefly, while discussions at greater length are devoted to the fundamental limitations of the various experimental techniques, and to some of the theoretical implications of the observations already made.

523.72+523.85]:621.396.822 2699
Radio Astronomy—(*Wireless World*, vol. 57, pp. 275–278; July, 1951.) A brief survey of modern equipment and techniques developed for the study of radio stars, meteors in the upper atmosphere, and solar and galactic noise.

523.72:621.396.822 2700
Radio Emission from the Sunspot of Central Meridian Passage 1950 June 14—A. Maxwell. (*Observatory*, vol. 71, pp. 72–74; April, 1951.) Observations made at Jodrell Bank indicated that the radiation intensity on a wavelength of 3.7 m ($10^{-19}w/m^2$ per cps) was unusually high for a sunspot group of this area (600 millionths of the sun's disk) which was, according to optical observations, declining. The magnetic field of the spot (3,600 gauss) was insufficient to account for this intense rf radiation. The high intensity persisted for 6 days, being asymmetrical about the time of central meridian passage, but coinciding in time with a brighter-than-normal patch of flocculi in the spot.

523.74 2701
A Forecast of Solar Activity—W. Gleissberg. (*Jour. Geophys. Res.*, vol. 56, pp. 294–295; June, 1951.) Earlier predictions (1121 of 1944) are vindicated. New predictions indicate that the next sunspot cycle will probably again be one of intense activity, with an unusually shallow minimum.

523.746"1951.01/.03" 2702
Provisional Sunspot-Numbers for January to March 1951—M. Waldmeier. (*Jour. Geophys. Res.*, vol. 56, p. 288; June, 1951; *Z. Met.*, vol. 5, p. 192; May/June, 1951.)

523.85:621.396.822 2703
Some Observations of the Variable 205 Mc/s Radiation of Cygnus A—C. L. Seeger. (*Jour. Geophys. Res.*, vol. 56, pp. 239–258; June, 1951.) U.R.S.I. September, 1950. General Assembly paper. A report on observations made between October, 1948 and May, 1950. Contrary to the results of Bolton and Stanley (2514 of 1948), the intensity of the radiation was found to vary with a mean period of about $\frac{3}{4}$ minute, which agrees with observations at lower frequency. Strong variations occur at all altitude angles of the source. These may be caused by ionospheric scattering.

550.38:621.396.11 2704
Relation between the Earth's Magnetism and the Propagation of Radio Waves between Washington and Bagneux—Lejay, Ardillon, and Bertaux. (*See* 2806.)

550.38 "1950.10/.12" 2705
International Data on Magnetic Disturbances, Fourth Quarter, 1950—J. Bartels and J. Veldkamp. (*Jour. Geophys. Res.*, vol. 56, pp. 283–287; June, 1951.)

550.38 "1951.01/.03" 2706
Cheltenham [Maryland] Three-Hour-Range Indices K for January to March, 1951—R. R. Bodle. (*Jour. Geophys. Res.*, vol. 56, p. 288; June, 1951.)

550.384.4 2707
The Daily Magnetic Variations in Equatorial Regions—A. T. Price and G. A. Wilkins. (*Jour. Geophys. Res.*, vol. 56, pp. 259–263; June, 1951.) A new analysis of the Sq field for the Polar Year 1932–1933 indicates that the maximum daily variation of H in equatorial regions occurs between the magnetic and dipole equators in South America and Africa, but to the south of both these equators in the Far East. The line of maximum variation swings seasonally in the direction opposite to the sun.

550.385/.386 2708
Sudden Commencements and Sudden Impulses in Geomagnetism: Their Hourly Frequency at Cheltenham (Md), Tucson, San Juan, Honolulu, Huancayo, and Watheroo—V. C. A. Ferraro, W. C. Parkinson, and H. W. Unthank. (*Jour. Geophys. Res.*, vol. 56, pp. 177–195; June, 1951.) During the period 1926–1946, the local time variations in the hourly frequency of sudden commencements appeared to be small; their frequency may be greatest around 1300 local time. The hourly frequency of sudden impulses was minimum at around 0800 and 2000 local time. The diurnal variations in frequency of sudden commencements and sudden impulses with a preliminary movement in the opposite direction, exhibit a local time effect with an afternoon maximum. Their frequency may depend on longitude. The curves for the annual mean number of sudden commencements and sudden impulses combined, and for annual mean sunspot numbers, show striking similarities.

550.385 2709
Principal Magnetic Storms [Sept. 1950–March 1951]—(*Jour. Geophys. Res.*, vol. 56, pp. 289–291; June, 1951.)

550.385:551.594.52 2710
The Southward Shifting of the Auroral Zone during Intense Magnetic Storms—T. Nagata. (*Jour. Geophys. Res.*, vol. 56, pp. 292–294; June, 1951.) Author's reply to comment noted in 873 of May (Ferraro).

551.510.5:621.396.9 2711
Observation of Radar Echoes coming from a Cloudless Region—J. Broc. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 2034–2036; May 28, 1951.) With radar equipment operating on a wavelength of 3.2 cm and a peak power of 30 kw, echoes of unexplained origin were observed on March 20, 1951, at Monaco. The echoes came from an apparent distance of 15 to 20 km, and from a height >1 km, the sky being clear.

551.510.535+551.594.5 2712
U.R.S.I.—I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951. (Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) Summaries are given of the following papers:

2—Martyn's Theory of Magnetic Storms and Auroras—H. G. Booker.
9—On the Definition of Virtual Height—J. Shmoys.
11—Fluctuations of F_2 Region between Stations separated by 100 to 150 Miles—H. W. Wells.
24—The Experimental and Theoretical Study of Ionospheric Absorption at 150 kc/s—A. H. Benner.
35—Southern Extent of Aurora Borealis in North America—C. W. Gartlein and R. K. Moore.
36—A.V.H.F. Propagation Phenomenon associated with the Aurora—R. K. Moore.
38—Magneto-ionic Multiple Splitting determined with the Method of Phase Integration—W. Pfister.

551.510.535 2713
Evidence for Ionosphere Currents from Rocket Experiments Near the Geomagnetic Equator—S. F. Singer, E. Maple, and W. A. Bowen, Jr. (*Jour. Geophys. Res.*, vol. 56, pp. 265–281; June, 1951.) Two rockets carrying total-field magnetometers were fired from sites 60 miles apart. In one case, the recorded magnetic field at distances between 20 and 105 km decreased according to expectations for a simple dipole field. In the second case, a discontinuity was observed in the altitude range 93 to 105 km. The results establish the existence of a current system in the E region causing the diurnal variation of the earth's magnetic field at sea level, and support the dynamo theory of the daily magnetic variation proposed by Balfour Stewart and Schuster. A brief report of the same work is given in *Phys. Rev.*, vol. 82, pp. 957–958; June 15, 1951.

551.510.535 2714
The Theory of Magneto-ionic Triple Splitting—O. E. H. Rydbeck. (*Chalmers Tekn. Högsk. Händl.*, no. 101, 40 pp.; 1951. In English.) The coupling coefficients between the magneto-ionic modes of propagation are calculated, and the method of excitation of the z mode analyzed in detail. The transformation and reflection coefficients of the modes are deduced as functions of the collisional frequency. Poeverlein's graphical method is applied to determine the refractive indexes and ray paths. Data from Kiruna are used to illustrate the main results of the theory. Meek's results (3221 of 1948) are also explained. The possibility that scattering discontinuities can excite the z mode at lower latitudes is discussed briefly. See also 1147 of June and *Onde élect.*, vol. 31, pp. 70–81 and 153–156; February and March, 1951.

551.510.535:621.396.11 2715
Change in the Nature of Medium-Wave Propagation at Sunset—Houtsmuller. (*See* 2809.)

551.594.5:621.396.11 2716
Radio Observations of the Aurora on November 19, 1949—N. C. Gerson. (*Nature* (London), vol. 167, pp. 804–805; May 19, 1951.) Using amateur reports of aurorally maintained reception, the position of the auroral reflecting belt is calculated, assuming that the height of reflection is 100 km, and that the ray paths are tangential to the earth. Possible causes of the "auroral modulation" are discussed. It is probable that this effect is due to changes of ionization density with position and time.

551.594.6:621.317.7.087:621.396.821 2717
An Atmospherics Waveform Receiver—W. J. Kessler. (Proc. I.R.E., vol. 39, p. 676; June, 1951.) The waveform is displayed on a cro, the horizontal sweep being triggered by the signal. This is delayed by 18-μs so that the leading edge is not lost. 50- or 100-μs markers are displayed on a separate sweep to avoid confusion with the signal. The display rate is limited to about 8 waveforms per second. Three sample waveforms showing multiple echoes are reproduced.

551.594 2718
The Flight of Thunderbolts [Book Review]—B. F. J. Schonland. Publishers: Clarendon Press, Oxford, and Oxford University Press, London, 1950, 152 pp., 15s. (*Nature* (London), vol. 167, pp. 787–788; May 19, 1951.) "An elementary but authoritative account" covering the development of knowledge regarding lightning discharges, methods of protection against lightning, the mechanism of electrification of thunderclouds, and radio atmospherics and their use in locating thunderstorms.

LOCATION AND AIDS TO NAVIGATION

621.396.9 2719
Port Approach and Berthing in Fog—F. J. Wylie. (*Jour. Inst. Nav.*, vol. 4, pp. 156–164; April, 1951.) A discussion of the role of shore-based radar in the berthing of ships in fog, and of the manner in which information obtained from radar or other aids should be presented to the master of a ship.

621.396.9:621.396.616 2720
Optimum Operation of Echo Boxes—W. M. Hall and W. L. Pritchard. (Proc. I.R.E., vol. 39, pp. 680–684; June, 1951.) The dependence of the optimum Q and maximum ring time of an echo box system on coupling method, pulse length, unloaded cavity Q, and transmitter-receiver properties, is examined theoretically. The results are shown graphically. The power taken by a direct-coupled box is also plotted as a function of pulse length, and the ratio of loaded to unloaded Q.

621.396.93:621.396.67 2721
U.R.S.I.—I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951. (Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) A summary is given of the following paper:
16—Antenna Systems for Radio Direction Finding—E. C. Jordan.

621.396.933 2722
Description and Evaluation of 100-Channel Distance-Measuring Equipment—R. C. Borden, C. C. Trout, and E. C. Williams. (Proc. I.R.E., vol. 39, pp. 612–618; June, 1951.) By combining the principles of operation of two separate earlier schemes for 50-channel equipment, a 100-channel system has been developed using only 20 distinct frequency channels (10 for interrogation and 10 for reply). These occupy a total bandwidth of 50 mc in the region of 1 kmc, together with 10 coded temporal relations between the interrogation and reply pulses. Possible identification schemes are discussed, and flight tests are described.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 2723
Photoconductivity of Caesium-Antimony Films—P. G. Borzyak. (*Zh. Tekh. Fiz.*, vol. 20, pp. 923–927; August, 1950.)

535.215 2724
Preparation of Photoconducting Cadmium Sulphide—R. E. Aitchison. (*Nature* (London), vol. 167, pp. 812–813; May 19, 1951.) Uniform layers of photoconducting Cds having any desired area, with thicknesses up to 5×10^{-4} cm, can be prepared by the slow evaporation in vacuo ($p\leqq10^{-6}$ mm Hg) of Cds precipitated from an aqueous solution.

537.226 2725
Present-Day Theories of Ferroelectricity—H. Lumbroso. (*Rev. Sci.* (Paris), vol. 88, pp. 239–247; October/December, 1950.) A general discussion, with particular reference to the properties of Rochelle salt and $BaTiO_3$. A bibliography of 18 items is appended.

537.311.33 2726
Transistors: Part 1—J. Malsch. (*Arch. elekt. Übertragung*, vol. 5, pp. 139–148; March, 1951.) A survey paper discussing the fundamental physical processes of conduction in semiconductors such as Si and Ge.

537.311.33 2727
Valence Semiconductors—F. Stöckmann. (*Naturwiss.*, vol. 38, pp. 151–154; April, 1951.) A survey paper, with numerous references, in which the conduction mechanism in semiconductors is considered from the point of view of developing materials with properties suitable for practical applications. Mixed-crystal (valence) semiconductors have the advantage that the concentration of impurity centers depends only on the composition of the material, and is thus controllable and thermally stable.

537.311.33:061.3 2728
The Seventh All-Union Conference on the

Properties of Semiconductors—(*Zh. Tekh. Fiz.*, vol. 21, pp. 231–242; February, 1951.) Report on a conference held by the Academy of Sciences of the U.S.S.R., and by the Academy of Sciences of the Ukrainian S.S.R., in Kiev, on the 14th to the 21st of October, 1950. Thirty-nine papers were read, under the following headings: general; theory of semiconductors; photoelectric phenomena in semiconductors; new types of semiconductors; surface and contact phenomena; thermal properties of semiconductors; technical application of semiconductors. Summaries of the papers and of the discussions are given.

537.311.33:546.3 2729

The Formation of Barrier Layers with the aid of Chemical Combinations in Welds—S. G. Kalashnikov and L. N. Erastov. (*Zh. Tekh. Fiz.*, vol. 21, pp. 129–134; February, 1951.) A simple method is described for obtaining a barrier layer by welding two metals which form a layer of high specific resistance in the weld. In this way, barrier layers were obtained between Sb and Mg and between Sb and Zn. The technique is described, and the results of an experimental investigation, including the voltage-current characteristics, are presented. A theoretical interpretation is given of the rectification produced. It is not suggested that the method is suitable for practical applications, since the rectifying properties of the welded pairs apparently deteriorate rapidly.

537.311.33:546.841-3 2730

Semiconductor Properties of Thoria in a Vacuum—G. Mesnard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1744–1746; May 7, 1951.) Experiments were carried out on thoria cylinders deposited by electrophoresis on pairs of parallel tungsten wires serving as heater and electrode systems. Properties investigated included electrical and thermal conductivity, and the rectification at the tungsten-thoria interface. The observed variation of conductivity with temperature gives support to the views of Loosjes and Vink (3208 of 1950) on the electronic processes involved, while the values obtained are comparable with those of Danforth and Morgan (2539 of 1950). Departure of the observed thermoelectric effect from values given by existing semiconductor theory, are explained by an interface, pd, which increases with rise of temperature. Rectification occurs as a result of the interface, pd, and the greater abundance of electrons in regions of higher temperature.

538.221 2731

International Conference on Ferromagnetism and Antiferromagnetism, Grenoble [July 3rd to 7th, 1950]—(*Jour. Phys. Radium*, vol. 12, pp. 149–508; March, 1951.) Full text of 49 papers presented at the conference.

538.221 2732

The Origin of Intermittent Activation in Ferromagnetic Materials—R. Forrer. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1746–1748; May 7, 1951.)

538.221 2733

The Magnetic Structure of High-Coercivity Alloys: Part 4—Magnetostriction Hysteresis in Alnico and Vicalloy Alloys—D. A. Shturkin and Ya. S. Shur. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1393–1399; November, 1950.) The results of an experimental investigation are analyzed on the assumption that these ferromagnetic materials consist of finely dispersed plate-formations insulated from one another, and that there is only one region of spontaneous magnetization within each formation.

538.221 2734

Magnetic Viscosity of Permalloy in Sinusoidally and Aperiodically Varying Fields—R. V. Telesnin and S. Z. Ushakov. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1366–1371; November, 1950.) Magnetic viscosity, i.e., the time delay of variations in magnetization with respect to variations in the intensity of the magnetic field, has previously been investigated by a number of authors separately for sinusoidally and for aperiodically varying fields. The present paper reports measurements made on the same sample for both types of field. A number of conclusions regarding magnetic viscosity are drawn.

538.221 2735

The Ferromagnetism of the β_1 Phase of Co/Zn Alloys—A. J. P. Meyer and P. Taglang. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1914–1916; May 21, 1951.) An experimental study of a series of alloys in which the proportion of Zn was varied from 42 per cent to 60 per cent.

538.221 2736

Results of Measurements on High-Permeability Ferrite Cores—M. Kornetzki. (*Z. angew. Phys.*, vol. 3, pp. 5–9; January, 1951.) The permeability characteristics of ferrite cores are discussed and compared with those of high-permeability stacked and wound cores. The ferrite cores may have a μ up to 3,500, nearly independent of frequency up to the gyromagnetic limiting frequency, between 1 and 6 mc. Above this frequency, μ falls. Due to capacitive eddy currents, a resonance occurs which may lead to an apparent increase in μ. The Curie point is lower the higher the permeability.

538.221:539.382 2737

Measurement of the Young's Modulus of Ferrites—L. Weil and L. Bochirol. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1807–1809; May 16, 1951.) The method used depends on finding the resonance frequency of magnetostrictively excited mechanical oscillations in annular specimens.

539.23 2738

Thin Films of Hydrocarbons formed by Electron or Ion Bombardment—H. König and G. Helwig. (*Z. Phys.*, vol. 129, pp. 491–503; April 28, 1951.) The mechanism by which films of solid hydrocarbons are formed from gas on the walls of experimental vacuum tubes, is described. Disturbing effects and useful applications of the film are discussed.

539.234:546.59 2739

The Crystallization of Very Thin Gold Films—A. Colombani and G. Ranc. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1344–1346; April 2, 1951.) Report of an experimental investigation of films deposited by evaporation on to an amorphous (e.g., plexiglas) or crystalline (e.g., NaCl) support. The nature of the film at different stages of development was deduced from the variations of its conductivity. Results are presented in graphs and discussed briefly.

546.287:537.533.8 2740

Silicone Oil Vapour and Secondary Electron Emission—A. Lempicki and A. B. McFarlane. (*Nature* (London), vol. 167, pp. 813–814; May 19, 1951.) Measurements of the "sticking" potential of a fluorescent powder, and of the secondary-emission coefficient for various surfaces, lead to the view that silicone oil vapor, currently used instead of mercury vapor in diffusion pumps, will produce obnoxious results on any surface bombarded by electrons.

549.514.51:621.396.611.21 2741

Temperature Dependence of Quartz Resonators—R. Bechmann. (*Arch. elekt. Übertragung*, vol. 5, pp. 89–90; February, 1951.) A note complementing earlier papers (3332 of 1942 and 2187 of 1943) and giving values of oscillation coefficients, piezoelectric coefficients, and capacitance constants and their temperature coefficients, for some bar and plate resonators.

621.3.011.5:[546.131+546.131.02 2742

The Dielectric Properties of Solid HCl and DCl—C. S. E. Phillips. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1924–1927; May 21, 1951.) Measurements made at frequencies ranging from 80 cps to 6 mc are reported.

621.314.63 2743

The Theory of Direct-Current Characteristics of Rectifiers—P. T. Landsberg. (*Proc. Roy. Soc. A*, vol. 206, pp. 463–477; May 22, 1951.) Image force can be taken into account very simply by making minor adjustments in the diffusion and diode theories. Expressions are obtained enabling detailed comparisons to be made with experimental data on the dc reverse characteristics of Cu_2O, Se, and Ge rectifiers, assuming (a) a Mott barrier, and (b) a Schottky barrier. Agreement is satisfactory. The effect of the image force on the charge-carrier distribution is illustrated, and a general relation between the two theories is established.

621.314.63 2744

Contributions to the Theory of Heterogeneous Barrier-Layer Rectifiers—P. T. Landsberg. (*Proc. Roy. Soc. A*, vol. 206, pp. 477–488; May, 22, 1951.) Assuming an arbitrary distribution of space charge in the barrier layer, the general form of the current-voltage relation is derived from both diode and diffusion theory. A connection, valid for most barriers, between this characteristic and the capacitance-voltage curve is pointed out. The Sachs breakdown voltage can be deduced from the latter characteristic. Assumption of a barrier, in which the distribution of impurity centers is established by a diffusion process, leads to more likely values for the rectifier parameters.

621.314.63 2745

Theory of the Contact between Two Semiconductors with Different Types of Conductivity—A. I. Gubanov. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1287–1301; November, 1950.) Various phenomena observed when a voltage is applied between two semiconductors with different types of conductivity (hole and electron) are discussed. To explain these phenomena it is suggested that a barrier layer of a type different from that considered by other investigators is formed at the contact. The theory of this layer is presented, and it is shown that it must possess high resistivity and exert considerable rectifying action. A formula is derived for determining the current through the contact. I/V characteristics, for both forward and backward directions, plotted from this formula show good agreement with experimental results.

621.315.61 2746

Dielectrics Made to Order—A. R. von Hippel. (*Electronics*, vol. 24, pp. 126–128; June, 1951.) Study of the synthesis of dielectric materials based on investigation of dielectric breakdown.

621.315.61:621.3.015.5 2747

Electrical Breakdown over Insulators in High Vacuum—P. H. Gleichauf. (*Jour. Appl. Phys.*, vol. 22, pp. 766–771; June, 1951.) Account of a practical investigation, in continuation of previous work (2454 of November). Breakdown voltage was measured for various electrode and insulator materials. Data establishing the relation between insulator length and breakdown voltage were obtained. The effect of the degree of roughness of the insulator surfaces in contact with the electrodes was investigated, and experiments were made in which one of the electrodes was separated from the insulator.

621.315.616.9:621.3.015.5 2748

The Intrinsic Electric Strength of Polyvinyl Alcohol and its Temperature Variation—I. D. L. Ball. (*Proc. IEE*, vol. 98, pp. 84–86; March, 1951.) Measurements were made at temperatures from −195° C to 90° C. Comparison with observations made on other high

polymers [see 1696 of 1949 (Bird and Pelzer) and 764 of 1947 (Austen and Pelzer)] suggests that the temperature variation of the intrinsic electric strength of these materials is determined by the dipoles present rather than by the physical structure.

621.318.4.042.15 2749

Investigations into the Possibility of using Suspensions of Ferromagnetic Particles in Liquid Dielectrics in place of Powder Cores—H. H. Rust. (*Arch. elekt. Übertragung*, vol. 5, pp. 67–76; February, 1951.) Plastic suspensions of, e.g., carbonyl iron in insulating oil were investigated. Coils were embedded in the suspension, and determinations were made of the resistance of the suspension with and without addition of a dipolar substance to the dispersive medium, and of the Q and self-inductance of the coil as a function of temperature and sedimentation time. The results are compared with corresponding values for powder-core coils. Variation of the effective permeability of the suspension due to thixotropic effects resulting from mechanical stress was investigated, and a number of practical applications are indicated.

621.319.45 2750

The Oxide Layer on Aluminium and the Temperature Dependence of the Capacitance of the Electrolytic Capacitor—S. S. Gutin. (*Zh. Tekh. Fiz.*, vol. 21, pp. 135–142; February, 1951.) A report on an experimental investigation, the main conclusions of which are as follows: (1) the oxide layer is of porous structure; (2) the temperature dependence of capacitance is determined by the action of the electrolyte in the pores; (3) covering the layer with a thin film of a solid dielectric reduces the temperature dependence of capacitance and ensures linear variation within the working range of temperatures.

669.018 2751

Resistance Alloys—H. Thomas. (*Z. Phys.*, vol. 129, pp. 219–232; February 13, 1951.) Measurements were made on Ni/Cr, Fe/Al, Ni/Al, Fe/Si, Ni/Cu/Zn, and Ni/Cu alloys. The resistivity/temperature curve is S-shaped, and the resistance is increased by heat treatment at low temperatures and is decreased by cold working. A physical explanation is advanced.

MATHEMATICS

517.94 2752

U.R.S.I.—I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951. (Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) A summary is given of the following paper:

40—Asymptotic Solution of Maxwell's Equation—M. Kline.

518.3 2753

The Smoothing of Experimental Curves—P. Vernotte. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1897–1899; May 21, 1951.)

518.3:514.6 2754

Nomogram and Slide-Rule for Solution of Spherical Triangle Problems found in Radio Communication—D. V. Dickson. (*Jour. Geophys. Res.*, vol. 56, pp. 163–175; June, 1951.)

681.142 2755

The Diagnosis of Mistakes in Programmes on the EDSAC—S. Gill. (*Proc. Roy. Soc. A*, vol. 206, pp. 538–554; May 22, 1951.) Description of methods, applicable generally to high-speed computers, for rapid diagnosis of mistakes due to faulty programming, including details of checking routines applicable particularly to the EDSAC.

517.53 2756

Equations Intégrales et Transformation de Laplace [Book Review]—M. Parodi. Publishers: Ministère de l'Air, Paris, France, 1950, 125 pp. (*Ann. Télécommun.*, vol. 6, p. 60; February, 1951.) Addressed primarily to mathematicians, but of interest also to engineers and physicists concerned with manipulating integral equations or using the symbolic calculus.

MEASUREMENTS AND TEST GEAR

529.786 2757

Accurate Time for Broadcast Studios—J. H. Greenwood. (*Electronics*, vol. 24, pp. 97–99; June, 1951.) Details of a system using a 60-cps standard frequency controlled by a 240-cps tuning fork to drive up to 10 synchronous clocks. Indications may be adjusted to agree with wwv signals to an accuracy within ± 0.1 second.

621.316.726.078.3 2758

Frequency Stabilization: Ultra-High-Frequency Discriminator—G. Pircher. (*Onde élect.*, vol. 31, pp. 144–152; March, 1951.) Methods of stabilizing uhf oscillators and various types of discriminator, are outlined. A detailed description is given of a simple discriminator, based on modifications of the amplitude and phase of the stationary wave pattern in a guide terminated by a load tuned approximately to the resonant frequency to be controlled. Figures are given of an actual equipment, using a klystron oscillator, covering the waveband 30 to 36 mm, and applications in the field of uhf measurements are indicated.

621.316.8:621.317.3.029.55 2759

A Resistor for High-Frequency Measurements—F. Lappe and K. B. Westendorf. (*Z. angew. Phys.*, vol. 3, pp. 29–32; January 15, 1951.) The resistor consists of a large number of thin parallel wires stretched along the surface of a cylinder and connected in parallel. The return path is provided by a coaxial metal cylinder inside or outside the wire cage. The time constants for such arrangements are calculated, and details are given of suitable constructions for particular applications.

621.317.32 2760

Arrangement for the Compensation and Measurement of Small Direct Voltages—G. Paldus. (*Arch. elekt. Übertragung*, vol. 5, pp. 135–138; March, 1951.) A device suitable for balancing out the steady component of an applied voltage, and thus making the whole of the galvanometer scale available for measuring the variable component, consists basically of oppositely connected thermocouples with separate heaters connected for differential control by a potentiometer circuit. Variants of the basic arrangement are described.

621.317.32.029.63 2761

Modern Methods of High-Frequency Voltage Measurement up to about 10,000 Mc/s—M. J. O. Strutt. (*Arch. tech. Messen*, no. 182, pp. T32–T33; March, 1951.) Discussion of sources of error in a diode voltmeter, and description of this and other measurement systems, the latter depending on current variations.

621.317.324:621.396.611.1 2762

Methods of Measuring Adjacent-Band Radiation from Radio Transmitters—N. Lund. (Proc. I.R.E., vol. 39, pp. 653–656; June, 1951.) Three methods are described using, respectively, two modulation tones of equal amplitude, normal modulating signals, or thermal-noise modulation. Good agreement between the last two methods shows the usefulness of thermal noise measurements, which require considerably less equipment. The first method normally gives only a qualitative estimate, but distortion measurements can be used to calculate the adjacent-band radiation, which is in reasonable agreement with the values found by the other methods.

621.317.335.3.029.63† 2763

The Measurement of Permittivity and Power Factor of Dielectrics at Frequencies from 300 to 600 Mc/s—J. V. L. Parry. (*Proc. IEE*, vol. 98, pp. 303–311; July, 1951.) A resonance method developed from that of Hartshorn and Ward (351 of 1937) for use at higher frequencies, is described. The variable capacitive elements are mounted in a re-entrant cavity which serves as a wavemeter for capacitance calibration. The accuracy for permittivity measurement is estimated to be within ± 1 per cent, and for power-factor measurement, to within $\pm 2\times 10^{-5}$ for values below 0.01, and $\pm 5\times 10^{-4}$ for higher values.

621.317.336.029.62/.63 2764

U.R.S.I.-I.R.E. Spring Meeting, Washington, D.C., April 16–18, 1951. (Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) A summary is given of the following paper:

3—Impedance Measurements in the 50 to 1,000 Mc/s Range—F. J. Gaffney.

621.317.42 2765

The Electron Multiplier as an Indicator of Weak Magnetic Fields—N. V. Krasnogorskaya. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1257–1266; October, 1950.) Experiments were conducted which show that an electron-multiplier tube with permanent magnets can be used as a magnetometer. It can be easily connected to an oscillograph and, being practically inertialess, it follows rapid variations of weak magnetic fields.

621.317.42 2766

Magnetic Field Measurements with Peaking Strips—J. M. Kelly. (*Rev. Sci. Instr.*, vol. 22, pp. 256–258; April, 1951.) The method is based on the oscilloscopic observation of voltage pulses induced in a coil wound round a length of high-permeability wire (i.e., a "peaking strip") arranged parallel to the magnetic field. Field strengths of the order of a kilogauss can be measured accurately to within ± 0.02 gauss.

621.317.725 2767

The Theory and Design of the Reflex Voltmeter—A. E. Budarov and L. E. Leykhter. (*Zh. Tekh. Fiz.*, vol. 21, pp. 77–91; January, 1951.) Range and scale-linearity of tube voltmeters are improved by the use of negative feedback. A detailed theoretical discussion of the operation of the voltmeter is presented, followed by a report on an experimental investigation confirming the theoretical findings. Two alternative circuits are described, and design details are considered. The various advantages of this type of voltmeter are enumerated. In addition to those already mentioned, they include: all-mains supply; great stability; very high input impedance; very long life of the measuring tube owing to the considerable reduction in the filament voltage; simplicity in production and operation; small weight and overall dimensions.

621.317.755.087.5 2768

The Speed of Recording of Cathode-Ray Traces by External Photography—V. P. Shasherin. (*Zh. Tekh. Fiz.*, vol. 21, pp. 92–103; January, 1951.) An attempt is made to provide a theoretical basis for determining the maximum speed of recording. The main factors involved are the conditions under which the oscillograph is used, the conditions under which the photographs are taken, the inertia of the cro screen, the method of scanning, and the characteristics of the photosensitive layer of the negative. Each of these factors is discussed in detail, and formulas are derived taking them into account. Some experimental data are also given.

621.317.763:621.396.615 2769

Two 'Grid Dip' Oscillators—C. Guilbert. (*Toute la Radio*, no. 154, pp. 82–87; March and April, 1951.) Description, with full constructional details, of two small tube-oscillator wavemeters. One uses a single "magic-eye" tube for both oscillator and indicator, and covers the range 3.3 to 95 mc. The second has a

normal indicating instrument, and covers the range 3.4 to 250 mc.

621.317.772.089.6 2770
Precision Calibrator for L.F. Phase-Meters—M. F. Wintle. (*Wireless Eng.*, vol. 28, pp. 197–208; July, 1951.) The calibrator provides a fixed-phase reference output and a calibrated variable-phase output. To improve accuracy, the phase shifting is performed at a harmonic of the output frequency, and the output is taken after frequency division. Details are given of the master oscillator, the main phase-shifting control, the frequency dividers, and selective amplifiers, together with examples of calculation of typical component values.

621.317.784 2771
Absolute Measurement of Microwave Power in Terms of Mechanical Forces—A. L. Cullen. (*Nature* (London), vol. 167, p. 812; May 19, 1951.) A radiation-pressure method is described for measuring the power in a low-loss cavity. Fox's rotary phase shifter (1255 of 1948) can be adapted to measure power absolutely without introducing reflection effects in the cavity.

621.385.001.4 2772
Valve Testing Methods and Apparatus of the French P.T.T. Administration—M. Ganet. (*Câbles & Trans.* (Paris), vol. 5, pp. 68–75; January, 1951.) A description of factory test methods and apparatus ensuring the reliability and uniformity of tubes supplied in bulk for use in telephone and telegraph line repeaters.

621.385.001.4 2773
Radio Valve Life Testing—R. Brewer. (*Proc. IEE*, vol. 98, pp. 269–274; July, 1951.) Tube failure may be due to emission failure, or to mechanical or electrical defects. The prediction of life is usually based on sample testing. The tests made may be for the purpose of quality control, pilot production, type establishment, or special applications, and vary accordingly. Sampling and test procedures, and suitable equipment are described. Evidence from life tests is summarized, and possible ways of speeding up procedure are outlined.

621.396.611.21 2774
The Measurement of the Amplitude of Oscillation of Quartz Crystals by the Interference Method—L. N. Borodovskaya and A. E. Salomonovich. (*Zh. Tekh. Fiz.*, vol. 21, pp. 221–224; February, 1951.) The method was used for measuring the oscillation amplitude of quartz crystals oscillating longitudinally, and for determining the relation between this amplitude and the voltages applied to, or taken from, the crystal. The theory of the method and the experimental results are discussed.

621.396.612.7.029.64 2775
A Spark Transmitter for Lightly Damped Centimetre Waves of Continuously Variable Frequency—H. Anders. (*Z. Phys.*, vol. 129, pp. 45–55; January 29, 1951.) A Hertzian dipole oscillator inside an almost closed cavity resonator is used as a continuously tunable generator over the 1- to 3-cm waveband. Since this arrangement produces a spectrum of oscillations, the radiation is passed through a second resonator whose spectrum coincides with that of the first at only one frequency. A nearly monochromatic radiation results, with intensity adequate for measurement purposes, and a logarithmic decrement of the order of 0.01.

621.396.615.015.7 2776
Narrow-Pulse Generator—S. F. Pearce and D. C. G. Smith: C. S. Fowler. (*Wireless Eng.*, vol. 28, pp. 225–226; July, 1951.) Further discussion of the difference between the measured and theoretical pulse lengths as described in 694 of April (Fowler). The discrepancy is ascribed to the finite operating time of the thyratron.

621.396.645.35:621.383 2777
A High-Sensitivity All-Mains Amplifier for Photocell Measurements—H. Tronnier and H. Wagener. (*Funk u. Ton*, vol. 5, pp. 1–4; January, 1951.) Modifications which improve the stability of the Etzold-type circuit (1324 of 1948) are discussed. The circuit described includes additional voltage stabilizers and two barretters, one to prevent overloading the main stabilizer, the other in the heater supply to the measurement circuit.

621.397.6.001.4 2778
Simple Test Generator for Television Sets using 441 and 819 Lines—J. Bergonzat. (*TSF pour Tous*, vol. 27, pp. 120–122; March, 1951.) Apparatus providing a test signal for adjusting and demonstrating television sets consists of a Colpitts oscillator generating frequencies from 40 to 60 mc. The various signals required to give a square-grid display are formed in four multivibrators. The circuit diagram, with component values, is given.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

522.615:522.2 2779
Servo Guider for Solar Telescopes—F. E. Fowler and D. S. Johnson. (*Electronics*, vol. 24, pp. 118–122; May, 1951.) Circuits incorporating photocells are used to correct the telescope direction for both hour angle and declination errors.

538.563:621-526 2780
Phase-Sensitive Detector Circuit having High Balance Stability—N. A. Schuster. (*Rev. Sci. Instr.*, vol. 22, pp. 254–255; April, 1951.) High stability of the detector balance, of great importance; e.g., in measurements of nuclear resonance where signal to noise ratio is low and an hour or more is required for signal measurements, is here achieved by using only one tube for the signal input, and switching its plate load by means of the reference signal.

621.316.7.076.7 2781
Improving Industrial Control Design—E. H. Vedder. (*Electronics*, vol. 24, pp. 104–106; May, 1951.) Based on a paper given in full in *Proc. NEC* (Chicago), vol. 6, pp. 471–479; 1950. Differences between requirements for industrial electronic apparatus and those for receivers are indicated. Long tube life and high reliability are important.

621.316.7.076.7 2782
The Electro-analogue, an Apparatus for Studying Regulating Systems: Part 1—Components and Functions—J. M. L. Janssen and L. Ensing. (*Philips Tech. Rev.*, vol. 12, pp. 257–271; March, 1951.) A universal model constituted by a network representing the process to be regulated, is combined with another model for the automatic controller which may act continuously or discontinuously. Oscillograms of typical response functions are given.

621.317.083.7:621.396.621 2783
Linear Discriminator for F.M. Telemetering—G. S. Sloughter and R. T. Ellis. (*Electronics*, vol. 24, pp. 113–115; June, 1951.) An asymmetrical flip-flop circuit is used to provide a stable FM discriminator for deviation ratios from zero to ±20 per cent, with subcarrier frequencies between 400 cps and 70 kc. The discriminator is linear to within 1 per cent over a deviation range of ±7.5 per cent. The particular application described is for the ground recording of flight characteristics of aircraft.

621.317.083.7:621.396.621.015.7 2784
Pulse-Width Discriminator—A. A. Gerlach and D. S. Schover. (*Electronics*, vol. 24, pp. 105–107; June, 1951.) Description of a simple high-stability pulse-width discriminator, handling pulses between 20 and 100 ms wide, used for channel identification at the receiving end of a three-channel telemetering system with pulse-width channel coding. Using pulse widths of 30, 60, and 90 ms, respectively, a tolerance of ±5 ms was satisfactory in the presence of noise.

621.365.029.63:537.523.5 2785
The Electronic Torch and Related High Frequency Phenomena—J. D. Cobine and D. A. Wilbur. (*Jour. Appl. Phys.*, vol. 22, pp. 835–841; June, 1951.) Description of an electronic torch operating at 1 kmc, and of some of the characteristics of the gaseous discharge produced. Power from a magnetron is coupled into a cavity, in turn coupled to a coaxial line through which gas is passed, and which is terminated by the torch section. The flame produced by polyatomic gases is capable of melting many refractory materials, due to the heat of association of the dissociated molecules. For a shorter account, see *Electronics*, vol. 24, pp. 92–93; June, 1951.

621.365.54† 2786
R. F. Induction Heating of Metals—M. Krüger and A. Koppenhöfer. (*Elektron Wiss. Tech.*, vol. 5, pp. 35–44; February and March, 1951.) A survey of the principles and apparatus used, with indication of specific applications.

621.383.001.8:621.798.4 2787
New Photoelectric Register Controls—G. M. Chute. (*Electronics*, vol. 24, pp. 92–97; May, 1951.) Description of three circuits for controlling packaging machinery. Thyratrons are used for feeding the correcting motor, and a three-photocell arrangement for obtaining high accuracy of register control.

621.384.6 2788
An Electronic Ram—W. Raudorf. (*Wireless Eng.*, vol. 28, pp. 215–221; July, 1951.) A simple method for accelerating electrically-charged particles is suggested, based on the transfer of the energy of a moving electric charge to a small fraction of that charge. A tubular arrangement is described in which the axial velocity of an electron beam is controlled by a longitudinal magnetic field. An extremely short and powerful em pulse is generated.

621.384.6 2789
Cyclic Accelerators—J. H. Fremlin and J. S. Gooden. (*Rep. Progr. Phys.*, vol. 13, pp. 295–349; 1950.) A review of the development of the more important particle accelerators requiring magnetic fields to control the particle orbits, with a discussion of the applications for which each is best suited economically.

621.384.612.2† 2790
The Synchrocyclotron at Amsterdam—F. A. Heyn. (*Philips Tech. Rev.*, vol. 12, pp. 241–256; March, 1951.) General description of the installation, with its oscillator and modulator, which produces in continuous operation deuterons with an energy of 28 mev.

621.385.3:578.08 2791
Wide Range Mechano-Electronic Transducer for Physiological Applications—S. A. Talbot, J. L. Lilienthal, Jr., J. Beser, and L. W. Reynolds. (*Rev. Sci. Instr.*, vol. 22, pp. 233–236; April, 1951.) A modified version of the RCA 5734 triode described in 3413 of 1947 (Olson) is used to measure forces of 100 mg to 25 kg.

621.385.83 2792
Energy Loss from Fast Electrons on passing through Foils (Multiple Scattering)—W. Schultz. (*Z. Phys.*, vol. 129, pp. 530–546; April 28, 1951.)

621.385.833 2793
Theory of the Independent Electrostatic [electron] Lens with Elliptical Central Electrode—É. Regenstreif. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1918–1920; May 21, 1951.) Explicit formulas are established for the gaussian trajectories in such a lens.

621.385.833 2794

Trajectories of Charged Particles Deflected Slightly from the Original Direction by an Electrostatic Field—B. M. Rabin and A. M. Strashkevich. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1232–1240; October, 1950.) Equations are derived determining the trajectories of the particles. Using these equations, it is possible to investigate the electronoptical properties of focusing and deflecting systems in three dimensions.

621.385.833 2795

The Optical Strength of Short Electron Lenses—O. I. Seman. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1180–1193; October, 1950.) It is shown that in determining the focal length of an electrostatic electron lens from the usual formula (1), an error as large as 100 per cent may be introduced. More accurate formulas, (8) and (21), are derived. The error introduced in determining the focal length of a magnetic lens from the usual formula, (2), is also estimated.

621.385.833:537.533.72 2796

The Significance of the Concepts 'Focus' and 'Focal Length' in Electron Optics, and Strong Electron Lenses with Newtonian Image—Formation Equation: Part 2—W. Glaser and O. Bergmann. (*Z. angew. Math. Phys.*, vol. 2, pp. 159–188; May 15, 1951.) Continuation of 2505 of November.

621.387:621.396.645.35 2797

Improved D.C. Amplifier for Portable Ionization Chamber Instruments—N. F. Moody. (*Rev. Sci. Instr.*, vol. 22, pp. 236–239; April, 1951.) The requirements of zero stability, adequate overall gain, and low battery consumption, are reconciled by the use of a two-stage reflex amplifier circuit. The anode load of the first (electrometer-tube) stage is returned to the screen grid of the second tube, a pentode cathode follower. The two stages are effectively cascaded, and a voltage gain >100 can readily be attained.

621.398:621.396.61 2798

A General-Purpose Remote Control System for Radio Transmitters—V. J. Tyler. (*Marconi Rev.*, vol. 15, pp. 61–81; 2nd quarter, 1951.) The general requirements of remote-control systems using land lines are discussed, and the advantages of a standard design having wide applicability are indicated. A brief description is given of a system which has been adapted for the control of three widely different transmitters, viz., a small communications transmitter, a pair of large broadcasting transmitters, and an aircraft navigation aid beacon transmitter.

PROPAGATION OF WAVES

538.566+621.396.11 2799

U.R.S.I.-I.R.E. Spring Meeting, Washington, D. C., April 16–18, 1951. (Proc. I.R.E., vol. 39, pp. 716–720; June, 1951.) Summaries are given of the following papers:

1—Recent Mathematical Developments in the Theory of Tropospheric Propagation—B. Friedman.

4—Air-to-Air Tropospheric Radio Propagation—G. B. Fanning and F. P. Miller.

5—The Effect on Propagation of an Elevated Atmospheric Layer of Nonstandard Refractive Index—L. H. Doherty.

6—Experimental Discrimination of the Factors in V.H.F. Radio Wave Propagation—A. W. Straiton and C. W. Tolbert.

7—Some Characteristics of 92.9-Mc/s Propagation observed at a Distance of 127 Miles—R. J. Wagner, Jr.

10—Dispersion of F_2-Layer Critical Frequencies—M. L. Phillips and H. S. Moore.

11—Fluctuations of F_2 Region between Stations separated by 100 to 150 Miles—H. W. Wells.

12—Angle of Arrival and Polarization at Fort Chimo—J. E. Hogarth.

13—Use of Long-Distance Back-Scatter to Determine Skip Distance and Maximum Usable Frequency—W. Abel.

14—Application of Punch Cards to the Analysis of Multipath Ionospheric Pulse Propagation Records—W. C. Moore.

19—Wave Propagation over Rough Surfaces—W. S. Ament.

20—Simultaneous Mobile Measurement of the Field Strengths of Two V.H.F. Radio Stations over Irregular Terrain—R. S. Kirby.

21—Suppression of Waves by Zonal Screens—H. E. Bussey.

22—The Effect of Low-Level Atmospheric Conditions on Overwater Interference Patterns at Microwave Frequencies—V. R. Widerquist and J. E. Boyd.

23—V. H. F. Tropospheric Recording Measurements of Plane and Circular Polarized Waves in the Great Lakes Area—J. S. Hill and G. V. Waldo.

25—The Measurement of the Polarization of Ionospheric Reflections at Low Frequencies—R. A. Helliwell, A. J. Mallinckrodt, D. A. Campbell, and W. Snyder.

26—Theoretical and Experimental Investigation of the Polarization of Long Waves reflected from the Ionosphere—J. M. Kelso and H. J. Nearhoof.

27—Polarization Measurements of Low-Frequency Echoes—E. L. Kilpatrick.

28—A Method for obtaining the Wave Solutions of Ionospherically Reflected Long Radio Waves including All Variables and their Height Variation—J. J. Gibbons and R. J. Nertney.

34—Very-High-Frequency Propagation in the Equatorial Region—O. P. Ferrell.

36—A V.H.F. Propagation Phenomenon associated with the Aurora—R. K. Moore.

37—Phase Velocity of Vertically Polarized Electromagnetic Waves in the Diffraction Region at the Surface of a Sphere—H. Lisman.

39—Electromagnetic Energy Density and Flux—C. O. Hines.

538.566 2800

The Radiation from a Magnetic Dipole in a Spherically Stratified Atmosphere—G. Eckart. (*Arch. elekt. Übertragung*, vol. 5, pp. 113–118; March, 1951.) German version of 2009 of 1950.

621.396.11+621.396.671 2801

Application of the Compensation Theorem to Certain Radiation and Propagation Problems—Monteath. (*See* 2648.)

621.396.11 2802

The Diurnal Variation of Signal Propagation [time] and Frequency between America and Europe—A. Stoyko and N. Stoyko. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1817–1818; May 16, 1951.) A study involving 6,000 recordings, was made of the reception at Paris of time signals from Annapolis (*NNS*, 23.75 m) over the period 1944 to 1949. Variation of propagation time with hour of day was observed, signals arriving in the morning and evening taking less time than those in the middle of the day. Recordings of signals from WWV show diurnal variations of received frequency with higher values during the hours 0500 to 1500 U.T. than during the rest of the day. The contradiction between these two sets of results is removed, if it is assumed that the number of hops in the propagation path changes suddenly when the F_1 layer reaches a certain height. This assumption is supported by angle-of-arrival observations.

621.396.11 2803

Variation of the Velocity of Propagation of Radio Waves—A. Stoyko. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1916–1918; May 21, 1951.) Recordings of time signals from Annapolis at Paris, and from Pontoise at Washington, during the period 1944 to 1949, yield a value of 271,317 km for the apparent velocity, as against the value of 290,000 km deduced from observations of round-the-world signals. The relation between propagation time and sunlit length of path is investigated, and observations of sw reception, recorded during 1931 to 1939, are re-examined, taking this relation into account. Another mean value of 273,000 km is obtained for the apparent velocity. It is concluded that the apparent velocity of sw signals in the ordinary case is less than for round-the-world signals, and is variable.

621.396.11:531.74 2804

A Phase-Comparison Method of Measuring the Direction of Arrival of Ionospheric Radio Waves—W. Ross, E. N. Bramley, and G. E. Ashwell. (*Proc. IEE*, vol. 98, pp. 294–302; July, 1951.) The apparatus described uses two pairs of spaced, coaxial loop antennas at a separation of 100 m. "The signals from the antennas in a pair are amplified by means of matched receivers. The phase difference between the output signals from these receivers is displayed direct on a cathode-ray tube as the angle of inclination of the trace. With pulsed signals emitted from a suitable transmitter, and with corresponding timing equipment in the receiver, the individual rays making up the total ionospheric signal may be separated from each other. The apparatus covers the frequency band 4 to 15 mc, and the rms error of phase measurement is about 1°. Site errors, however, set a more severe limit to the accuracy of the directional measurements than do instrumental errors. In practice it is found that, for example, over an oblique path corresponding to a range of 700 km, bearings can be measured with an accuracy of about 1°, while the angle of elevation can be measured with an accuracy better than about 1½° so long as it exceeds 30°. These limitations mean that angles of elevation of *E*-layer reflections cannot be measured accurately at long range. It is possible, however, to obtain measurements of useful accuracy of the angle of elevation of *F*-layer reflections at ranges up to 1,000 km or more. Bearings can be measured accurately at all ranges and for all reflections."

621.396.11+538.566]:550.38 2805

The Effect of the Earth's Magnetic Field on Short-Wave Communication by the Ionosphere—G. Millington. (*Proc. IEE*, vol. 98, pp. 314–319; July, 1951.) Digest of IEE monograph. A re-presentation of the magneto-ionic theory for oblique transmission through the ionosphere. The quartic equation of the theory is solved graphically, and simple expressions are derived by the method of stationary phase for the differential coefficients for the group time, lateral deviation, and specific attenuation of the ray path. Numerical integration along the path is discussed with special reference to the relation of oblique to vertical transmission, and some preliminary results are given.

621.396.11:550.38 2806

Relation between the Earth's Magnetism and the Propagation of Radio Waves between Washington and Bagneux—P. Lejay, J. M. Ardillon, and G. Bertaux. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1975–1976; May 28, 1951.) Records of reception from WWV made at the Laboratoire National de Radioélectricité have been studied in conjunction with records from the magnetic observatory at Chambon-la-Forêt. Close correlation is established between received field strength and magnetic activity. Graphs for February and July, 1950, show that the ionospheric disturbances, as indicated by reduced field strength, last for several days after the end of the magnetic disturbances, both in winter and summer. For weak magnetic disturbances, the field-strength fluctuations on 15 and 20 mc are parallel in winter, but opposed in summer. This difference is attributed to a reduction of muf.

The results are supported by observations of WWV 10-mc transmissions made at Turin.

621.396.11:550.385 2807
Enhanced Trans-equatorial Propagation following Geomagnetic Storms—O. P. Ferrell. (*Nature*, (London), vol. 167, pp. 811–812; May 19, 1951.) Radio-amateur reports of abnormal communication in the 6-m band during 1949 show that maximum usable frequencies are abnormally high during or immediately following the longer magnetic storms. The equatorial positive phase (891 of 1950) may continue for up to one day after the end of the storm.

621.396.11:551.510.535 2808
The Mechanism of *F*-Layer Propagated Back-Scatter Echoes—A. M. Peterson. (*Jour. Geophys. Res.*, vol. 56, pp. 221–237; June, 1951.) U.R.S.I.-I.R.E. 1950 Meeting paper. The results of multifrequency observations agree with theory if scattering is assumed to occur at the earth's surface rather than in the *E* region. The leading edge of the scatter echo corresponds to energy returned from beyond the edge of the skip-zone, while energy from the skip-zone edge returns with greater delay, the time difference becoming larger as the *F*-layer vertical incidence critical frequency is approached. The rapid buildup of echo amplitude which follows a sharply defined minimum time delay is explained as a focusing phenomenon.

621.396.11:551.510.535 2809
Change in the Nature of Medium-Wave Propagation at Sunset—J. Houtsmuller. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 85–114; discussion, pp. 115–116; March, 1951.) Investigations made under the auspices of the International Broadcasting Organization during the latter part of 1947 are reported. They provide important information regarding the influence of soil conditions at transmitter, receiver, and, in the case of double-hop transmissions, earth reflection point, and regarding the dependence of ionosphere properties on the sun's position. The observations indicate that electrons recombine not only with positive ions, but also with neutral atoms and molecules.

621.396.11:551.594.5 2810
Radio Observations of the Aurora on November 19, 1949—Gerson. (*See* 2716.)

621.396.11.029.6 2811
A Study of Tropospheric Scattering of Radio Waves—A. W. Straiton, D. F. Metcalf, and C. W. Tolbert. (Proc. I.R.E., vol. 39, pp. 643–648; June, 1951.) The following results, substantiating the scattering theory of Booker and Gordon (1757 of 1950), were observed at frequencies in the neighborhood of 100 mc: (a) at great distances, for horizontal polarization, energy was received over a considerable range of elevation angle for weak signals, but was restricted to the horizontal direction for strong signals; (b) while for vertically polarized waves, attenuation with distance agreed with the refracted-wave theory, for horizontally polarized waves, attenuation was less than expected. At about 9 kmc, the cone of received energy was restricted to a few degrees above the horizon, again in conformity with the scattering theory.

621.396.81 2812
Prediction of Short-Wave Propagation Conditions based on Ionosphere Observations—K. Rawer. (*Arch. elekt. Übertragung*, vol. 5, pp. 154–167; April, 1951.) A survey is given of methods practiced by the French government service. The upper and lower propagation frequency limits as determined, respectively, by ionosphere penetration and *D*-layer absorption, are discussed, and their relation to propagation path examined. The methods of ionosphere prediction take account of geographical position, daily and seasonal variations, and sunspot cycle. Forty literature references are included.

621.396.81 2813
Sunspots or Position of the Sun?—R. G. Sacasa. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 11–22; June, 1950.) N.B.S. predictions are compared with those made by the method of 2614 of 1950. Graphs of field strength at Madrid of 10-, 15- and 20-mc transmissions from Washington for January, 1949, and January, 1950, are given.

621.396.81.029.6 2814
Predicting Performance of U.H.F. and S.H.F. Systems—E. A. Slusser. (*Electronics*, vol. 24, pp. 116–121; June, 1951.) Aids provided to simplify signal-strength calculations for uhf radiating systems for a wide range of conditions include: nomograms for (a) the power gain of antenna systems, (b) field strength as a function of distance, frequency, and antenna constants, (c) spatial attenuation between given antennas, (d) effect of ground reflections, (e) calculation of optical and radio horizons, Fresnel zone radii, and shadow losses. Receiver noise and atmospheric absorption are considered, and a detailed example of the calculations for a complete system is given.

621.396.812:551.510.535 2815
Fading of Short Wireless Waves due to the Interference between the Magneto-ionic Components—S. N. Mitra. (*Indian Jour. Phys.*, vol. 24, pp. 197–206; May, 1950.) Periodic fading of a downcoming wave may be due to interference between the two magneto-ionic components when the difference between their equivalent heights of reflection is changing at a uniform rate. A twin-loop antenna system that accepts only one of the components, is described. Its use in investigations of this type of fading is illustrated, and the effect of ionospheric irregularities with random motion and with steady drift, is discussed. See also 442 of 1950.

621.396.812.3 2816
Comparison of Field-Strength Fluctuations of the Swiss Broadcasting Stations in the First Fading Zone—C. Glinz. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 29, pp. 1–25; January 1, 1951.) The measurements made at St. Gall on transmissions from Beromünster, reported in 2036 of 1949 (Gerber and Werthmüller), are compared with measurements for the Sottens and Monte Ceneri stations over the period 1936 to 1950. The seasonal variations of amplitude for Sottens are in phase with those for Beromünster, while those for Monte Ceneri are opposed in phase. For all three stations, the amplitude of fluctuation varies inversely as sunspot activity. The results are used to calculate the absorption in the *D* layer shown in graphs. Stratification of the *E* layer is discussed. Correlation of the results with variation of the sw attenuation/frequency curve for different values of sunspot activity is attempted, but cannot be accomplished without knowledge of the nocturnal critical frequencies of the lowest ionosphere layers. After March, 1950, when the wavelength of Monte Ceneri was changed from 257 m to 539 m, the field-strength fluctuations for this station resembled those for Beromünster.

RECEPTION

621.396.621 2817
Up-to-Date High-Fidelity Receiver: Cathode-Coupled Frequency Changer—J. Rousseau. (*TSF pour Tous*, vol. 27, pp. 112–113; March, 1951.) Certain modifications to the receiver described earlier (982 of May) are explained, and the advantages of using separate tubes for frequency changer and oscillator, with cathode coupling, are discussed in detail. Circuits and component values for use with various tubes are given.

621.396.621 2818
The T.R.153 [receiver]—B. Morisse. (*Toute la Radio*, no. 153, pp. 56–59; February, 1951.) Description of a high-quality broadcast receiver, incorporating the cathamplifier circuit [78 of February (Parry)] in the audio amplifier.

621.396.621:621.396.615 2819
A High-Stability Directly-Calibrated Oscillator—G. L. Grisdale. (*Marconi Rev.*, vol. 15, pp. 89–96; 2nd quarter, 1951.) The oscillator described was designed for use in a series of communication receivers, and covers the frequency range 2 to 4 mc. It is hermetically sealed and has a frequency/temperature coefficient $<5\times10^{-6}$ per degree C. A direct-reading frequency scale allows accuracy of tuning to within ±1 kc, and the frequency changes by <1 part in 10^6 for a 1 per cent change in tube anode or filament voltage.

621.396.621:621.396.619.13 2820
F.M. Modulation in U.S.W. Broadcasting Receivers—A. Nowak. (*Telefunken Ztg.*, vol. 23, pp. 139–153; December, 1950.) Three different methods of demodulation are considered, the discussion being illustrated by reference to the basic circuits of a series of receivers produced by the Telefunken company. The operation of the ratio detector is studied in detail. An expression is derived for the optimum amplitude limiting on which the design of the diode coupling circuit can be based. The effect of adding resistance to the hf and dc circuits to stabilize the output, is discussed. The simpler demodulation method of using an AM detector, with operating point on the side of the resonance curve, is applied in the cheaper receivers.

621.396.621:621.396.619.13 2821
Commercial U.S.W. Receivers—G. Vogt. (*Telefunken Ztg.*, vol. 23, pp. 155–166; December, 1950.) Requirements for lf fidelity, hf selectivity, and sensitivity in different FM receivers for use in rebroadcasting stations, are discussed. Performance figures and details are given for four types of receiver. A monitor receiver with frequency range 87 to 110 mc has an intermediate frequency of 10.7 mc. A general-purpose unit for reception of programs for relaying has two intermediate frequencies of 16 mc and 4 mc, respectively, giving improved selectivity and general performance. Other receivers on this principle are used for multichannel reception, operating on a fixed carrier frequency, and incorporating FM feedback to the second detector through a phase-equalizing network.

621.396.621:621.396.65 2822
Design Considerations for a Radiotelegraph Receiving System—J. D. Holland. (*Proc. IEE*, vol. 98, pp. 253–262; July, 1951.) Difficulties encountered in the reception of frequency shift and AM telegraph signals over radio links are discussed. Greater transmission efficiency can be obtained by the former system. Fading and interference affect both systems and give rise to distortion. The three main components of distortion are defined, and bandwidth requirements before and after demodulation are discussed. The need for exceptional frequency stability is stressed in relation to the reduction of errors for both methods. Diversity operation is considered, and an AM diversity method is described.

621.396.621.5 2823
A Dual-Diversity Frequency-Shift Receiver—D. G. Lindsay. (Proc. I.R.E., vol. 39, pp. 598–612; June, 1951.) Reprint. See 1761 of 1950.

621.396.622 2824
Sensitivity and Operating Condition of Mixing Circuits using Diodes—H. F. Mataré. (*Arch. elekt. Übertragung*, vol. 5, pp. 57–66 and 119–124; February and March, 1951.) Mixing problems in the decimeter-wave region are discussed. On the assumption that the noise is determined mainly in the if stages, a simple circuit is derived for the equivalent noise source, from which the operating condition and corresponding sensitivity can be found. The inherent

feedback of the diode is taken into account. The "equivalent conversion noise resistance" is introduced to explain the behavior when using harmonics for the mixing step. Transit-time effects are considered. A method is presented for predicting the sensitivity. Calculated values are compared with results measured at a wavelength of 55 cm, and good agreement is found.

621.396.6/.8 2825
Reception Radiophonique, Parasites (Broadcast Reception, Interference) [Book Review]—Y. Angel. Publishers: Eyrolles, Paris, France, 1950, 166 pp., 880 fr. (*Ann. Télécommun.*, vol. 6, p. 59; February, 1951. *Rev. gén. élect.*, vol. 60, p. 88; March, 1951.) Complementary to an earlier work on broadcast receivers (738 of 1950). This volume deals with interference and its suppression, and antennas and long-distance reception.

STATIONS AND COMMUNICATION SYSTEMS

621.3.015.7(083.7) 2826
Standards on Pulses: Definitions of Terms—Part I, 1951. (Proc. I.R.E., vol. 39, pp. 624–626; June, 1951.) Reprints of this Standard 51 IRE 20 S1, may be purchased while available from the Institute of Radio Engineers, 1 East 79 Street, New York, N. Y., at $0.50 per copy.

621.39.001.11 2827
Adaptation of Message to Transmission Line: Part 2—Physical Interpretation—B. Mandelbrot. (*Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 2003–2005; May 28, 1951.) A cybernetically reversible complex transmission process is investigated by breaking it down into elementary differentiation and integration processes, corresponding to the quantization of the message into words, followed by its reconstruction. The operation of the system is considered in terms of entropy variations.

621.39.001.11 2828
A Functional Equation of Information Theory—J. Ville. (*Câbles & Trans.* (Paris), vol. 5, pp. 76–83; January, 1951.) To estimate the quantity of information delivered by a given source of independent signals of unequal probabilities of occurrence, the "transmission cost" of each signal is considered. An expression is obtained for the transmission cost of a signal as a function of the number of messages transmitted. The frequencies of occurrence of the signals being known, a minimum transmission cost will be attained when the signals are actually transmitted at these frequencies. The functional equation thus permits calculation of transmission-cost deviation, and of its lower limit. For a given occurrence frequency, the amount of information delivered is closely related to its transmission cost; hence, an estimate may be obtained which depends not upon the number of possible values ascribable to the signal, but only upon the relative frequencies of these values.

621.39.001.11:621.396.619 2829
Limited-Spectrum Signals and Modulation Theory—J. Oswald. (*Câbles & Trans.* (Paris), vol. 5, pp. 54–59; January, 1951.) Amplitude modulation may be defined by means of linear "commutation" operators, which are associated with the product of any function having an integrable square, multiplied by a periodic function of limited bandwidth. By the use of these operators, the spectral composition of a signal may be defined for any modulating function of finite bandwidth. Analogous but nonlinear operators may be defined for the case of frequency modulation. See also 210 of February.

621.395.43:621.395.822.1 2830
Crosstalk in Amplitude-Modulated Time-Division-Multiplex Systems—J. E. Flood and J. R. Tillman. (*Proc. IEE*, vol. 98, pp. 279–293; July, 1951.) Mathematical analysis of the crosstalk occurring when energy proper to one channel arrives during the time allocated to another. This may arise from coupling and decoupling circuits, stray capacitance, the use of cable links, and low-pass filter networks. Both Fourier analysis and operational calculus are used, and experimental results confirming the analysis are presented. Improvements in crosstalk ratio may be obtained by inductance compensation in amplifiers. When many distorting networks are present, improvement may result from the use of nonrectangular pulses.

621.395.64 2831
Portable Repeater used for Broadcast Programmes—F. A. Peachey, G. Stannard, and C. Gunn-Russell. (*Electronic Eng.* (London), vol. 23, pp. 162–166; May, 1951.) Describes the principles and details of apparatus used by the B.B.C. for relaying over G.P.O. lines. Equalizers are connected at the input to the repeater amplifier, and in its negative feedback path. The complete assembly comprises two equalizer-amplifier units (one spare), one switching, telephone and dc testing unit, and batteries.

621.395.66 2832
Level Regulation and Telesignalling on the Paris-Brive-Bordeaux-Toulouse Coaxial Cable—R. Sueur, F. Job, and F. Le Guen. (*Câbles & Trans.* (Paris), vol. 5, pp. 40–53; January, 1951.) The system includes both automatic and tele-regulated repeaters, the equipment comprising temperature compensators, voltage-actuated distortion regulators, telecontrol and telesignalling apparatus. Circuit diagrams and explanations of operation are given.

621.396.41 2833
Note on the Coding of a Multiplex Transmission—F. H. Raymond. (*Ann. Télécommun.*, vol. 6, pp. 55–57; February, 1951.) Rules are formulated for deriving arithmetically a series of code numbers corresponding to given combinations of signals in m channels. It is shown that the simplest procedure is to derive the code signals for the m channels of a time-division multiplex system.

621.396.619.13:621.317.35 2834
The Component Theory of Calculating Radio Spectra with Special Reference to Frequency Modulation—N. L. Harvey, M. Leifer, and N. Marchand. (Proc. I.R.E., vol. 39, pp. 648–652; June, 1951.) To find the response of a filter to an FM signal, a vectorial representation of phase is used. On a plane rotating at the filter response frequency, a fixed "filter-response" vector is drawn. The FM signal vector rotates relative to this. The instantaneous angular difference between the vectors being θ, it is assumed that the filter current is proportional to the signal and to $\cos\theta$, and that the "filter-response" vector will adjust its phase to extract maximum energy from the signal during each modulation cycle. The filter current is then calculable, and the results for sinusoidal modulation agree with previous methods of analysis.

621.396.619.13:621.396.813 2835
Nonlinear Distortion in Frequency Modulation—E. Kettel. (*Telefunken Ztg.*, vol. 23, pp. 167–174; December, 1950.) Analysis, particularly of amplitude distortion in different demodulator circuits, and of frequency distortion in the transmission and reception circuits handling the FM signal. Theoretical distortion factors for harmonics of different orders are calculated in these cases. The actual distortion effects occurring in practice are due to combination tones, and their relative magnitudes are often measured instead of distortion factor. In FM systems, the relation between these two factors varies. Methods of distortion measurement for FM systems are outlined.

621.396.65 2836
Telecommunication Networks using U.H.F. Radio Links—L. U. Marin and J. J. R. Moral. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 23–44; June, 1950.) Part 1 critically surveys the evolution and present day state of radio-link technique, giving, in tabular form, brief details of 23 existing or projected links. Part 2 makes concrete proposals for the establishment of four links branching from Madrid, to connect the twenty principal Spanish towns. Frequency modulation is advocated. The method of determining the sites and calculating signal to noise ratio is outlined, with numerical examples in illustration. An estimate is made of the equipment required and the cost of the installation and maintenance of the system.

621.396.65:621.394.3 2837
Teleprinter System using Radio Links (Tor)—H. C. A. van Duuren. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 53–67; March, 1951.) A two-way system is described in which, on reception of a mutilated character, the receiver stops operating and the local transmitter signals the fault back to the remote station. The remote receiver actuates its associated transmitter to repeat the message, starting with the mutilated character. A seven-unit code is used for the transmission, with conversion from and to the usual five-unit code.

621.396.712.029.6(43) 2838
U.S.W. Broadcasting—H. Bredow. (*Telefunken Ztg.*, vol. 23, pp. 123–126; December, 1950.) Advantages of usw technique are outlined, and details of the German network operating in the 90-mc band are shown.

654.01 2839
Optimum Junction Points in Telephone and Communication Networks—K. Dorr. (*Arch. elekt. Übertragung*, vol. 5, pp. 125–134 and 197–201; March and April, 1951.) Vector analysis is used to determine the location of junction points in star and mesh systems so as to give the most economical arrangements. Mechanical projection apparatus is described for dealing with particular problems. Several examples are considered, including the broadcasting of television from aircraft, and the location of relay stations in usw radio link systems.

SUBSIDIARY APPARATUS

621.314.63 2840
Measurement of Characteristics of Rectifier Disks for Different Harmonic Contents—F. Jerrentrup. (*Z. angew. Phys.*, vol. 3, pp. 14–21; January, 1951.) The behavior of dry rectifiers under different operating conditions is investigated experimentally. Measurement circuits used for operation with steady dc, pulsed ac, etc., are shown, and the conductance characteristics of Cu_2O, Fe-Se, and Al-Se disks, are compared. Forward and backward conductance are treated separately. Typical parameters for the three types are tabulated.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24 2841
Television Transmission in Local Telephone Exchange Areas—L. W. Morrison. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 280–294; March, 1951.) The use of lines for transmitting video signals over short distances between pickup camera, local studio, and points on intercity networks, is discussed. The physical and electrical properties of the various types of cable, and the design and performance of video amplifiers and equalizers now in use are described.

621.397.3.083:621.392.53 2842
Storing Video Information—A. L. Hopper. (*Electronics*, vol. 24, pp. 122–125; June, 1951.) A fused silica bar operating on 54 mc is used to provide a delay of 63.5 μs, the time required to

scan one television line, thus making possible a comparison of signal amplitudes along adjacent lines. Inclusion of a filter with a frequency response inverse to that of the bar, enables the effective pass band to be doubled. A bandwidth of 14 mc at the 3-db points is obtained, the signal to noise ratio exceeding 54 db.

621.397.5:535.62 2843

The Physiological Basis of Colour Television—Y. Le Grand. (*Onde élect.*, vol. 31, pp. 173–177; April, 1951.) Physiological considerations suggest that the seeing of color television depends on the fact that the ability of the human eye to distinguish detail is less when the color of the picture alone changes than when the level of illumination varies, rather than on the possibility that the resolving power of the eye may be lower in the blue than in the other parts of the visible spectrum.

621.397.5:535.623 2844

Field-Sequential Color Companion—E. Cohen and A. Easton. (*Electronics*, vol. 24, pp. 110–114; May, 1951.) An adapter unit for connection by a lead and plug to the video-stage tubeholder of a black-and-white-television receiver, for reception of the C.B.S.-system color transmissions. Scanning is at 144 frames per second, interlaced, and a three-color rotating disk is arranged in front of the tube face. Time-base generators, power supplies, and motor synchronizing circuits, are incorporated.

621.397.5(083.74) 2845

Conversion of Television Standards—A. Cazalas. (*Onde élect.*, vol. 31, pp. 178–183; April, 1951.) The possibility of using television signals conforming to a first standard to provide a service conforming to another standard, is examined. Difficulties arising from modification and mixing of the signals generated, and those due to interlaced scanning and phasing effects, are set out. The technique is suggested of using the transmission by the first standard to produce an electrical image on an auxiliary screen, which is then used to produce the transmission conforming to the second standard. Apparatus for achieving this is described.

621.397.7 2846

Rack-Mounted Flying-Spot Scanner—R. L. Kuehn and R. K. Seigle. (*Radio & Telev. News, Radio Electronic Eng. Suppl.*, vol. 16, pp. 7–9; April, 1951.) Description of self-containing scanning equipment designed for 2 inch $\times$2 inch standard slides. Circuit details and block diagrams of the cathode-ray tube scanner, and associated amplifier and photomultiplier units, are given.

621.397.6:535.88 2847

The RCA PT-100 Theater Television Equipment—R. V. Little, Jr. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 317–331; March, 1951.) Description of commercial equipment.

621.397.6.001.4 2848

Simple Test Generator for Television Sets using 441 and 819 Lines—Bergonzat. (*See* 2778.)

621.397.61:621.396.615.142.2 2849

Five-kw Klystron U.H.F. Television Transmitter—H. M. Crosby. (*Electronics*, vol. 24, pp. 108–112; June, 1951.) Description of the G.E. Type Z 1891 klystron, which has an output $>$5 kw at frequencies between 475 and 890 mc, and its use in a high-power uhf television transmitter. Using this klystron as video amplifier, a power gain of 50 is obtained, with low noise, over a band of 5 mc with a response flat to within 1 db.

621.397.621.2:535.62 2850

Constructing the Tricolor Picture Tube—D.G.F. (*Electronics*, vol. 24, pp. 86–88; May, 1951.) The cathode-ray tube for receivers using the R.C.A. color-television system is described. Details are given of photoengraving processes suitable for the manufacture of the apertured metal mask, and also of the method of preparing the stencil for the phosphor-dot screen in accurate alignment with the mask so as to ensure that only the appropriately colored dots are scanned by any one gun.

621.397.621.2:535.88 2851

Projection Kinescope 7NP4 for Theater Television—L. E. Swedlund and C. W. Thierfelder. (*Jour. Soc. Mot. Pic. & Telev. Eng.*, vol. 56, pp. 332–342; March, 1951.) The features of this 7-inch, 80-kv kinescope include (a) high-efficiency, low-color-shift, white fluorescent screen; (b) adequate high-voltage insulation; (c) electrostatically focused high-current beam; (d) magnetic deflection through a narrow angle to conserve deflection power and maintain focus over the picture area.

621.397.621.2.001.4 2852

Picture-Tube Performance—K. A. Hoagland. (*Electronics*, vol. 24, pp. 123–125; May, 1951.) The current required in the focusing coil of television-receiver cathode-ray tubes under given pattern conditions is discussed. It is found that wide tolerances are necessary for this current if the position of the aid is defined relative to the tube neck instead of relative to the gun. Corresponding considerations apply in the case of tubes with es focusing. The vertical resolution of picture tubes is also investigated, and on the basis of subjective tests, an optimum value is found.

TRANSMISSION

621.316.726:621.396.61 2853

Communications Technique in French Aviation—Babin. (*Onde élect.*, vol. 31, pp. 161–172; April, 1951.) An account of the methods used for frequency stabilization, both for continuous ranges and for fixed frequency channels. Three distinct techniques for using the stable frequencies generated by quartz oscillators are indicated. The quartz may be used directly, or with the interposition of a discriminator, or with locking of the controlled circuits, as in a multivibrator. Several types of equipment actually in use are described.

621.396.61/.62 2854

Army Walkie-Talkie in Mass Production—R. J. (*Electronics*, vol. 24, pp. 98–100; May, 1951.) A portable sixteen-tube FM vhf transmitter-receiver, giving speech communication over a range of 5 miles. By use of subminiature tubes and Ge diodes, the weight and size have been reduced to half that of the equipment used in the 1939 to 1945 war.

621.396.61:534.861 2855

Justification for raising the Standard of Broadcast Transmissions—Beurtheret. (*See* 2622.)

621.396.61:621.396.615.16 2856

Specification for U.S.W. F.M. Broadcasting Transmitters set up by the Broadcasting Corporations of the [Western German] Federated Republic—F. Gutzmann. (*Telefunken Ztg.*, vol. 23, pp. 127–130; December, 1950.) General discussion of harmonics, interference, modulation, audio frequency range, carrier-frequency constancy, and distortion.

621.396.619.13:621.396.615 2857

A Simple Method of Producing Wide-Band Frequency Modulation—H. Rakshit and N. L. Sarkar. (*Indian Jour. Phys.*, vol. 24, pp. 207–222; May, 1950.) Full description of the principles and experimental arrangement including a phase-discriminator afc system for carrier stability. See 2362 of 1949.

621.396.619.13:621.396.615.16 2858

The Series of Transmitters for U.S.W. Broadcasting—W. Burkhardtsmaier. (*Telefunken Ztg.*, vol. 23, pp. 131–138; December, 1950.) Illustrated description of the construction, design, and operating characteristics of various transmitter units developed for the German FM broadcasting service. The complete installation provides an output of 10 kw in the frequency range 87.5 to 100 mc. Frequency swing is 75 kc at 100 per cent modulation, distortion factor about 1 per cent. The two self-contained preamplifier stages are designed to feed a 60-Ω asymmetric load, and can be coupled to an antenna for radiation at powers of 250 w or 3 kw. Specially designed tubes are used [see 2872 (Rothe et al.) below]. Details are given of the completely enclosed, single-tube construction of the 10-kw stage.

TUBES AND THERMIONICS

535.215.4 2859

Investigations of the External Photoelectric Effect in Cuprous and Cupric Oxide—L. Meyer-Schützmeister. (*Z. Phys.*, vol. 129, pp. 148–160; February 13, 1951.) *I/V* characteristics for semiconductor and metal photocathodes were compared, using a photocell of specially adapted construction. For metal cathodes, the negative anode voltage at which cutoff occurs is independent of the material. For semiconductors, the cutoff voltage does depend on the material. The results suggest that the energy levels of the electrons released by the external photoelectric effect are lower in semiconductors than in metals, by about 0.1 v for Cu_2O, and by about 0.55 v for CuO.

621.383.4 2860

Critical Review of Semiconductor-Photo-Resistance Cells—H. Helbig. (*Elektron Wiss. Tech.*, vol. 5, pp. 57–62; February and March, 1951.) An attempt to define the useful field of application of such cells, with special reference to the CdS type. Mainly useful where intense illumination is to produce a current of the order of a milliampere. Where changes do not take place rapidly, they can be used in relay circuits, for sound-film recording, and for qualitative indication of X radiation. They are unsuitable for accurate measurements.

621.383.4 2861

Operating Limits of Photoresistances—H. Müser. (*Z. Phys.*, vol. 129, pp. 504–516; April 28, 1951.) The useful range of operation is limited by the resistance noise in the semiconductor; the magnitude of this is calculated. It is generally greater than the thermodynamic fluctuations due to the temperature radiation of the surroundings. This noise limitation cannot be overcome by using devices such as long-period galvanometers, narrow-band amplifiers, etc., to suppress the noise.

621.383.4 2862

The Characteristics and Properties of Lead Sulphide Photoresistors—B. T. Kolomiets. (*Zh. Tech. Fiz.*, vol. 21, pp. 3–11; January, 1951.) A report on an extensive experimental investigation. Results are presented in tables and curves. The main conclusion is that these resistances are highly suitable for a number of practical applications.

621.385 2863

Design of Robust, Shock-Proof Electronic Valves—G. Lewin. (*Le Vide*, vol. 6, pp. 974–978; March, 1951.) The effect of mechanical shock on a tube is analyzed. Its magnitude depends on the rigidity of the assembly. On this basis, design fundamentals are developed. Data are given regarding the physical properties of the metals used, and the correct use of fragile materials such as glass.

621.385.001.4 2864

Radio Valve Life Testing—Brewer. (*See* 2773.)

621.385.029.64/.65 2865

New Travelling-Wave Valves for Microwaves—H. H. Klinger. (*Arch. elekt. Über-*

tragung, vol. 5, pp. 167–168; April, 1951.) Two tubes are briefly described, whose operation is based on direct exchange of energy between electrons and electromagnetic wave. Both use arrays of metal dipoles of delay-lens type to slow down the waves. One of the tubes is a modified drift-space klystron; the other uses a reflector to bend the electron beam, which is injected at an angle to the delay field. Inherent noise is low; useful wavelength range is probably limited to 1 to 2 cm.

621.385.029.64 2866

On the Theory of Electron Wave Tubes—O. E. H. Rydbeck and S. K. H. Forsgren. (*Chalmers Tekn. Högsk. Händl.*, no. 102, 29 pp.; 1951. In English.) Equations are derived first for the waves produced in a single-beam tube with strong axial magnetic focusing. Both beam waves and guide waves are present. When the beam is shot into a neutral ionized gas, strong traveling waves may be excited. The effect of reducing the magnetic field is investigated. Analysis for a two-beam tube indicates that klystron waves, plasma waves, and interaction waves, are all present, the distribution of energy between them depending on the manner of excitation. The theoretical results are in agreement with measurements on a 3-kmc two-beam tube developed at the Chalmers Research Laboratory.

621.385.032.212 2867

A New Modulated Light Source—J. A. Darbyshire. (*Electronic Eng.* (London), vol. 23, pp. 167–169; May, 1951.) The Ferranti GMC 6 "crater lamp" is described and compared with the older MAC 4. It has a higher light output for given current, and better linearity. Coating of the viewing window by evaporated barium has been eliminated. Operating conditions for particular applications are stated.

621.385.15 2868

Secondary Electron Multipliers—N. Schaetti. (*Z. angew. Math. Phys.*, vol. 2, pp. 123–158; May 15, 1951.) A survey paper reviewing secondary emission phenomena, the production of suitable emitting surfaces, types and operating characteristics of photo-multipliers, and applications in various fields. A bibliography comprising 80 items is provided.

621.385.18 2869

Controllable Gas Diode—E. O. Johnson. (*Electronics*, vol. 24, pp. 107–109; May, 1951.) The object of the device, which is called a "plasmatron," is to combine the continuous control afforded by the vacuum tube with the low impedance of the thyratron. It is operated at an anode potential too low to cause ionization. A discharge is set up between the anode and an auxiliary cathode, the discharge current being controlled by a small, conventional hard tube. The current flowing between anode and main cathode can be controlled by varying the auxiliary discharge current with fairly good linearity, a current ratio of 90:1 having been obtained.

621.385.2 2870

Thermodynamics of a Two-Cathode System—H. Dormont. (*Le Vide*, vol. 6, pp. 979–984; March, 1951.) The results obtained by Champeix (2586 of November) are shown to be valid only for the limiting case where the temperature difference between the two electrodes is small compared with their mean temperature. Discussion of the source of thermionic emission in oxide cathodes is continued. Further experimental data are required.

621.385.2:537.525.92 2871

The Space-Charge Smoothing Factor—C. S. Bull. (*Proc. IEE*, vol. 98, p. 278; July, 1951.) Discussion on 2058 of September.

621.385.3/.4 2872

U.S.W. Transmitting Valves—H. Rothe, W. Engbert and H. Kraft. (*Telefunken Ztg.*, vol. 23, pp. 175–182; December, 1950.) For the final power stages of transmitters operating in the 100-mc band (a) the grounded-grid triode, and (b) the grounded-cathode tetrode, are of particular interest. To maintain the electrode connections as lossless as possible, disk seals are most suitable. The high power necessarily drawn by the control circuit in (a) is largely available as useful power at the anode. In (b) the much lower power required increases with rising frequency due to the inductance of the cathode leads. The construction and operating characteristics of two 10-kw triodes and three tetrodes for powers of 0.25 kw, 1 kw, and 3 kw, are shown.

621.385.38 2873

Grid Current and Grid Emission Studies in Thyratrons—the Trigger-Grid Thyratron—L. Malter and M. R. Boyd. (PROC. I.R.E., vol. 39, pp. 636–643; June, 1951.)

621.385.38:537.315 2874

The Distribution of the Electric Field in a Three-Electrode Gas-Discharge Tube with a Large Back Voltage—V. D. Andreev, L. E. Levina, and B. G. Mendelev. (*Zh. Tekh. Fiz.*, vol. 21, pp. 149–154; February, 1951.) The potential distribution in the plasma between the anode and grid of a Hg-vapor tube during the reverse half-cycle was investigated by taking oscillograms of probe currents. On the basis of the results obtained, the division of the voltage between the electrodes is discussed.

621.396.615.142:[537.525.6:538.56 2875

Electron Plasma Oscillations—G. Wehner. (*Jour. Appl. Phys.*, vol. 22, pp. 761–765; June, 1951.) "Electron plasma oscillations are excited by a beam of fast electrons in a stabilized low-pressure mercury discharge. Probe measurements reveal that the uhf fields are localized in thin layers, the plasma density and frequency of which follow Langmuir's law. The beam of fast electrons traversing such an oscillation layer becomes velocity modulated, and excitation conditions result from drift time and bunching considerations similar to those in a klystron. A sealed-off tube described covers a frequency range between 800 and 4,000 mc (five modes) without changing or matching any resonance circuit."

621.397.61:621.396.615.142.2 2876

Five-kw Klystron U.H.F. Television Transmitter—Crosby. (*See* 2894.)

621.396.822 2877

The Nature of Currents producing the Main Component of Radio Valve Noise—A. R. Shul'man. (*Zh. Tekh. Fiz.*, vol. 20, pp. 1505–1508; December, 1950.) A noise component of frequency between 50 and 100 cps usually appears in the anode circuit of a tube with an indirectly heated cathode. Experiments were conducted to determine the origin of this component, and it is concluded that it is due to current between the heater and the cathode produced by thermal emission of electrons from the heater on to the cathode, and sometimes from the cathode on to the heater. The value of the current is affected by impurities, and can be considerably reduced by a suitable treatment of the heater material.

621.396.822 2878

Induced Grid Noise in Triodes—A. van der Ziel. (*Wireless Eng.*, vol. 28, pp. 226–227; July, 1951.) The Llewellyn-Peterson theory of tube operation at uhf (2578 of 1944) is applied to extend Bell's formula (1833 of 1950) for induced grid noise in triodes and pentodes. Better agreement with experimental results is thus obtained.

621.396.822:621.396.645.3.029.42 2879

Experimental Investigation of Fluctuation Phenomena Limiting the Operation of Direct-Voltage and Very-Low-Frequency Amplifiers—K. Kronenberger. (*Z. angew. Phys.*, vol. 3, pp. 1–5; January, 1951.) Results are presented of noise measurements on tube amplifiers under different operating conditions. Fluctuations of heater and anode supply voltages constitute the most important source of noise. When these voltages are nearly constant, i.e., vary by $<10^{-5}$ per cent, in the oxide-cathode tube operating below 0.1 cps, the effect of emission-drift is the most serious, and above 0.1 cps it is the flicker effect. For the tungsten cathode, the anomalous flicker effect determines the sensitivity. Since the noise voltage of an unwanted signal is generally higher at the low-frequency end of the spectrum, advantages are gained by mechanical conversion of a direct voltage to high-frequency voltage before amplification.

621.385.832 2880

Le Tube à Rayons Cathodiques [Book Review]—L. Chrétien. Publishers: Chiron, Paris, France, 1950, 191 pp., 585 fr. (*Ann. Télécommun.*, vol. 6, p. 58; February, 1951.) A manual for practicians and students, dealing with the use of the cathode-ray tube in measurement, radar, and television applications.

MISCELLANEOUS

621.396.001.5 2881

Engineering Research of the British Broadcasting Corporation—(*Engineering* (London), vol. 171, pp. 793–795; June 29, 1951.) A brief survey of investigations in progress, including work on high-definition and color television, interference between transmitters sharing a frequency channel, impulsive interference, and methods of economizing on bandwidth; field-strength mapping; design and performance of transmitting antennas, using models for much of the work; development of broadcast and special-purpose receivers; electroacoustics. See also *Elec. Rev.* (London), vol. 148, pp. 1341–1343; June 29, 1951, and *Elec. Times*, vol. 119, pp. 1098–1100; June 28, 1951.

621.396.001.57 2882

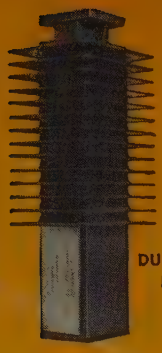
Technical Development and Research by Telefunken during the War—H. Lux. (*Telefunken Ztg.*, vol. 23, pp. 11–26; September, 1950.) A brief review is given of advances in the following branches: tube development, including hf, metal/ceramic and tr switching tubes, high-power types with thoria cathodes, and transit-time types; medium- and high-power transmitters and measuring equipment; decimeter-wave technique in communications, including radio links; radar and radio navigation; piezoelectric crystals; hf heating technique; general research on propagation in the wavelength range 20 m to 10 cm, on antennas, on receiver sensitivity, and on hf measuring techniques; af techniques and electroacoustics; and techniques related to television.

621.38 2883

Electronic Fundamentals and Applications [Book Review]—J. D. Ryder. Publishers: Prentice-Hall, New York, N. Y., 806 pp., $9.00. (*Radio & Telev. News, Radio Electronic Eng. Suppl.*, vol. 16, p. 26; April, 1951.) "Written to give the student a knowledge of . . . the physical principles underlying electron tubes, the characteristics of the tubes themselves, and the electrical circuits in which they are used . . ."

621.39 2884

Telecommunications Principles [Book Review]—R. N. Renton. Publishers: Pitman, London, Eng., 450 pp., 37s. 6d. (*Electrician*, vol. 146, p. 1131; April 6, 1951.) Covers the City and Guilds examination syllabus, Grades I, II, and III. Many examples are worked out. "The work can be most highly recommended."



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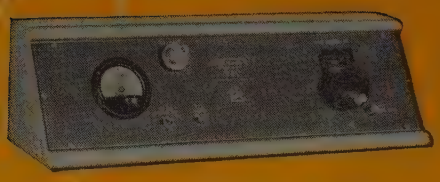

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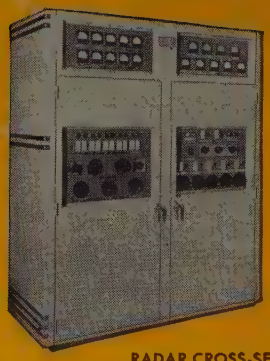

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Industrial Engineering Notes[1]

Television News

A television station, XELD-TV, Matamoras, Mexico, just across the border from Brownsville, Texas, has started operation, according to an announcement. Effective radiated power is 2.8 kw on Channel 7. In addition to Brownsville, the station covers Harlingen, Weslaco, and McAllen in the Rio Grande Valley area. XELD-TV claims its coverage area includes 306,348 United States citizens and another 200,000 in Mexico. . . . The Mexican Secretaria de Communicaciones **has authorized the construction of a new television station at Tampico, Mexico.** The new outlet will be affiliated in ownership with XES, Tampico, and XEW, Mexico City. American made equipment costing $80,000 will be used. . . . **Two uses of television for mass education have been announced.** The Federal Civil Defense Administration is conducting a training program using theatre television in four eastern cities, and the Army Signal Corps has received a mobile television system which is of value in telecasting intricate field exercises and "piping" the pictures to classrooms, observers, or maneuver umpires. Under the FCDA plan, 11,000 civil defense workers see the live program, which originates in Washington, in theatres in New York, Baltimore, Philadelphia, and Washington. If the experiment is successful, FCDA said a series of training programs may soon be inaugurated to give civil defense workers throughout the country standardized instructions. The new Signal Corps television unit is housed in four specially built busses each 31 feet long. It reportedly was conceived by the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., and built by RCA under an Army research and development contract. Included are three field cameras, 10 receivers, a large-screen TV projector, intercommunication radio facilities, power units, and complete microwave transmitting, monitoring, and receiving equipment. . . . **The FCC has granted Sylvania Electric Products Incorporated a construction permit for a new experimental television station at Emporium, Pa.** The station will operate on UHF frequencies 509–529 and 870–890 megacycles with transmission limited to test patterns and/or monoscopes. Sylvania said it wanted the station "to obtain actual field tests from radiated TV signals on UHF oscillator mixers and amplifier tubes and circuits associated therewith; to determine long-term reliability of operation of such devices under conditions of use similar to their ultimate purpose and to improve such devices in view of the results obtained from the tests, and to study the feasibility of extending TV service to small isolated communities surrounded by hills, by the use of low power satellite stations." . . . **The British will have to wait a long time for color television** the British Broadcasting Corporation has indicated in its annual report. The BBC said it wants set makers to design color TV receivers and other equip-

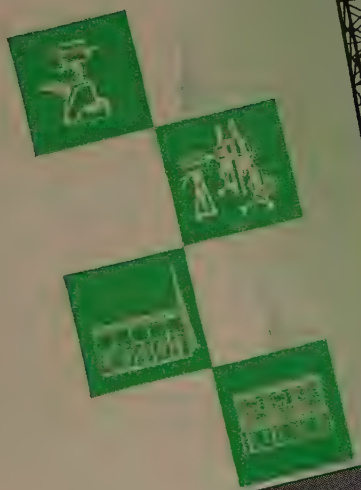
(Continued on page 68A)

Guessing!

... OR FACTUAL PLANNING

for that television station

The proper choice and arrangement of equipment are of the utmost importance in a successful TV station operation. A guide, reflecting the unequalled experience of Du Mont in this field, is now offered in the form of an illustrated, easy-to-follow book. Detailed renderings along with exploded views and systematic floor plan arrangements follow the text graphically. Complete breakdown of equipment complements with approximate prices are indicated throughout. Be sure to have this information in your file whether you are planning a new station or the expansion of your present operations.



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OSCILLATOR

Dependable for Audio, TV, Lab. use

Here is a fine instrument you can always depend upon for engineering service or laboratory use. Its tuned fundamental frequency circuit provides a permanently locked calibration. Just look at these specifications:

FULL RANGE—Sine wave, 20 cycles to 200 KC with continuously variable frequency selection. Improved logarithmic calibration means no crowding at either end of dial. Four decade ranges provide over 33 inches of linear calibration.
ACCURACY—Frequency calibration accurate to within 3% or 1 cycle. Complete stability is accomplished with a constant waveform—even at the extreme ends of the range. Spurious "beats" or signals are impossible in the output.
OUTPUT IMPEDANCE—Five values: 10, 250, 500, or 5,000 ohms impedance as well as additional resistive range, all controlled by a single selector switch.
OUTPUT POWER—500 milliwatts.
OUTPUT CONTROL—Continuously variable from zero to maximum.
WAVEFORM—Less than 5% Harmonic Distortion at all frequencies between 30 and 15,000 cycles.
FREQUENCY CHARACTERISTIC—Plus or minus 1 db between 30 and 15,000 cycles.
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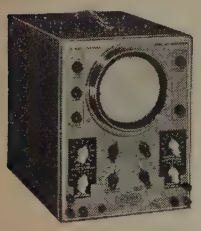
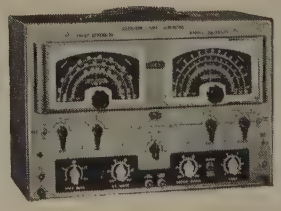
VOLTAGE—For 105/120 volts, 50/60 cycles AC; 60 watts.
DIMENSIONS—13″ wide, 9½″ high, 9⅝″ deep. Net weight, 26 lbs.
Furnished complete with all tubes.
Model 655. Users' Net Price, $135.00



Two Other Fine Jackson Instruments



MODEL CRO-2 OSCILLOSCOPE

5-inch oscilloscope having a vertical sensitivity of .018 RMS v.p.i. and band width flat within 1.5 db from 20 cycles thru 4.5 Mc. Linear sawtooth sweep oscillator 20 cycles thru 50 KC per second in 5 steps. A standard voltage provided for determining unknown Peak to Peak potentials of all waveforms. Has reversible vertical polarity and return trace blanking.

MODEL TVG-2 GENERATOR

Sweep Oscillator in three ranges from 2 Mc thru 216 Mc, all on fundamentals. Reversible sweep direction. Sweep width variable .1 Mc thru 18 Mc. Marker covers 4 Mc thru 216 Mc. Crystal Oscillator to use as Marker or Calibrator. Video Modulation from external source for using actual video signal for check, or for use with Audio Oscillator to produce bars for linearity checks.

JACKSON ELECTRICAL INSTRUMENT CO.
"Service Engineered" Test Equipment
DAYTON 2, OHIO
In Canada: The Canadian Marconi Co.

Industrial Engineering Notes

(Continued from page 66A)

ment so it "can thoroughly be studied and tested before any decision about a future color television system for public service is made." . . . The FCC on Wednesday announced that it has postponed until February 25, 1952, the start of its **hearing on the allocation of frequencies and promulgation of rules and regulations for a proposed theatre television service.** The time for filing in this proceeding also has been extended to January 25, 1952. . . . **The Danish Minister of Finance has recommended that this country continue its experimental television service,** RTMA has learned. The Minister reportedly was reluctant to continue the project for fear that the importation of television parts and equipment would deplete the nation's scarce hard exchange. Producers, however, have maintained that they have orders pending from Argentina and Brazil for spare parts for TV receivers that would more than counterbalance any expenditure of hard currency on the importation of required materials. At present there are about 500 television sets in Denmark and production of 1,500 sets annually is contemplated for the home market. The manufacturers reportedly expect to produce all parts needed in the TV sets. At present Dutch tubes are being used. . . . Officials of the Civil Communications Section, General Headquarters, Supreme Commander for the Allied Powers, are extremely skeptical **concerning the possibility of a television network for Japan in the immediate future, as was reported earlier.** The Civil Communications Section believes the Japanese are not in a position to afford television sets at their present price and that Japanese radio interests cannot finance the operation of a large-scale TV station and program project. It is their opinion that television for Japan could not be expected on other than an experimental basis for at least 10 years. The Japanese Broadcasting Corporation which is government owned, has done some experimentation in television and reportedly has long-range plans for TV Broadcasting. Several Japanese radio and electrical products manufacturers are understood to be engaged in research on video equipment. In general, Japanese technicians are reported to be more optimistic about the prospects for television in Japan than are the Civil Communications Section officials. . . . SODRE, an agency of the Uruguayan Government, **is accepting bids for equipment, material, and installations needed for the construction of a complete television system to be installed in Montevideo.** No standards have been specified although it is understood that American standards of 6 megacycles have been advocated by local authorities. A frequency range within channels 2–6 is being considered and the line-frame question is to be decided on the basis of tests in the area. The American system of television reportedly is favored by the local technicians because the system is in use in Argentina and Brazil. The station is to be

(Continued on page 76A)

ENGINEERS

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LONG-RANGE MILITARY AIRCRAFT PROGRAM

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Unusual opportunities for Aerodynamicists, Stress Engineers, Aircraft Designers and Draftsmen, and specialists in all phases of aircraft engineering. Engineering skills other than aircraft may be adaptable through paid training program. Also openings for

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Engineering Personnel Office

SECTION P-8

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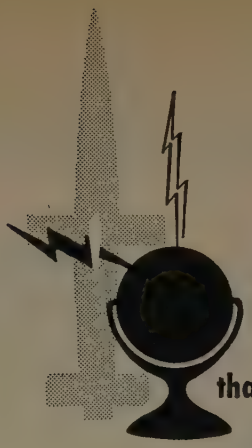

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that sunshiny, smog-free city on the coast of

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Unusual opportunities for those experienced in the design and analysis of Radar and Missile Guidance Systems.

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A NEW SINGLE-SIDEBAND RECEIVER

Complete triple-diversity system in compact single-rack mounting for receiving all forms of double and single-sideband transmission . . . including reduced-carrier single-sideband operation . . . with exalted-carrier detection to eliminate distortion caused by selective fading.

●

For program, voice, tone-multiplex and twin-channel operation; optimum performance in rejecting interference; protected against jamming.

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Diversity combining system automatically selects strongest signal and rejects weak signals, resulting in optimum signal-to-noise ratio at all times.

●

Employs standard communications receivers. Each receiver section has individual power supply and may be operated independently if desired.

●

Provides a receiver of peak performance for today's techniques as well as tomorrow's advanced requirements in single-sideband communications.

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Substantially increases reliability of long-range radio circuits of governmental services, air lines, international press and broadcast facilities.

WRITE FOR DETAILS

CROSBY LABORATORIES, INC.
126 Herricks Road — Mineola, New York

Industrial Engineering Notes

(Continued from page 68A)

operated by the state under a franchise to a private firm. . . . The nation's 108th television station, WLTV, Atlanta, Georgia, started operation on channel 8. The new station is owned by Broadcasting Incorporated, and utilizes the facility vacated by WSB-TV, Atlanta, which moved to Channel 2 and increased its power at the same time. . . . The FCC has granted **Paramount Television Productions Incorporated permission to test its Telemeter system of subscriber television.** The authority is for 90 days and Paramount will use the facilities of KTLA (TV), Los Angeles. The tests will be conducted between midnight and 9 a.m. without public participation. The Telemeter system is based on a scrambled picture transmission with a coin-operated mechanism on the receiver to operate the unscrambler.

Industry Statistics

Production of radio and television receivers in the first eight months of 1951 decreased 3.5 and 13 per cent, respectively, under the output in the corresponding period of 1950, according to industry estimates compiled for RTMA by Haskins & Sells. Radio receiver production in 1951 amounted to 8,977,232 units compared with 9,303,000 sets in the first eight months of last year. The TV output totaled 3,633,516 in the first eight months of this year and 4,184,400 sets in the corresponding 1950 period. . . . With RTMA statistics indicating **total industry output of about 4,000,000 television receivers during the first nine months of this year** RTMA President McDaniel estimated the output of TV sets in 1951 at between 5,000,000 and 5,250,000 as compared with 7,400,000 in 1950.

NBS News

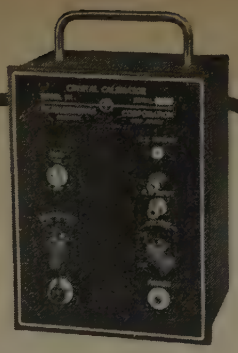
The National Bureau of Standards has announced a **new technique developed by J. H. Park which increases the "writing speed" of a high-voltage oscillograph** to three-fourths the velocity of light. High intensification of the electron beam reportedly is obtained momentarily by superimposing a steeply rising voltage pulse on the steady voltage applied to the discharge tube of the oscillograph. The resultant increase in the intensity of the trace makes writing speeds up to 9,100 inches per microsecond easily visible. Complete details are carried in the *NBS Technical News Bulletin* for October, 1951. . . . **A. V. Astin, former associate director of the National Bureau of Standards, has been named Acting NBS Director** by Secretary of Commerce Charles Sawyer. He succeeded E. U. Condon, who resigned recently to become Research Director for the Corning Glass Corporation.

Mobilization

Defense Mobilizer C. E. Wilson has announced **the appointment of Franklin Lamb as an Assistant to the Director of the Office of defense Mobilization.** Mr.

(Continued on page 78A)

Measurements Corporation



MODEL 111

CRYSTAL CALIBRATOR

For The Frequency Calibration Of Equipment In The Range Of

250 Kc. to 1000 Mc.

(To within .25 Mc.)

Frequency Accuracy: 0.001%

The Model 111 provides a test signal of crystal-controlled frequency and has a self-contained detector of 2 microwatts sensitivity.

For calibration and frequency checking of signal generators, transmitters, receivers, grid-dip meters, etc.

MEASUREMENTS CORPORATION

BOONTON NEW JERSEY

Measurements Corporation
MODEL 79-B

PULSE GENERATOR

REPETITION RATE: 60 to 100,000 pulses per second.

PULSE WIDTH: Continuously variable from 0.5 to 40 microseconds.

RISE TIME: Approx. 0.25 microseconds.

OUTPUT VOLTAGE: 150 volts (peak) positive.

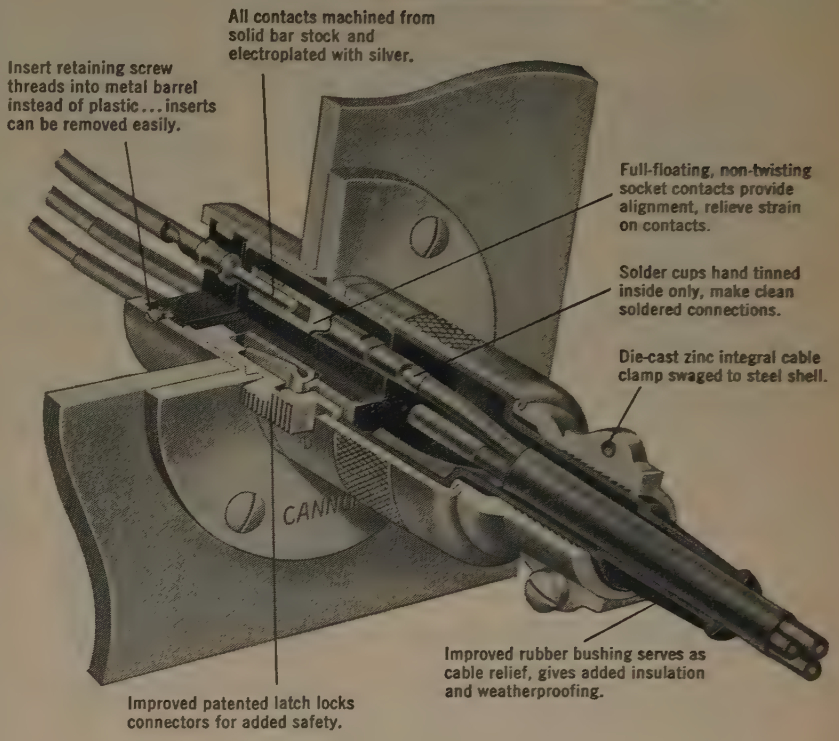
POWER SUPPLY: 117 volts, 50/60 cycles.

MEASUREMENTS CORPORATION

BOONTON NEW JERSEY

Here's why those in the know —demand

CANNON PLUGS


All contacts machined from solid bar stock and electroplated with silver.
Insert retaining screw threads into metal barrel instead of plastic... inserts can be removed easily.
Full-floating, non-twisting socket contacts provide alignment, relieve strain on contacts.
Solder cups hand tinned inside only, make clean soldered connections.
Die-cast zinc integral cable clamp swaged to steel shell.
Improved rubber bushing serves as cable relief, gives added insulation and weatherproofing.
Improved patented latch locks connectors for added safety.

If you talk to sound technicians anywhere you'll find Cannon Type P connectors are the accepted standard of quality... taking a beating day in day out where frequent changes in circuits are required on all kinds of jobs up to 30 amp. capacity.

The close attention to important details called out in the above illustration is typical of the care used in the design and construction of all Cannon Plugs—the world's most complete line.

The above type series is distributed through selected franchise distributors. The line is fully described in the Type P Bulletin. Engineering bulletins describing each of the many basic types of Cannon Plugs will be sent on request.

P-3

Type P insert arrangements include 2-3-4-5-6 and 8 contacts. All contacts are 30 amp. capacity except those in P-8 layout which are 15 amp. Full scale layouts, front view pin insert, engaging side, shown at right.

P-8

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Since 1915

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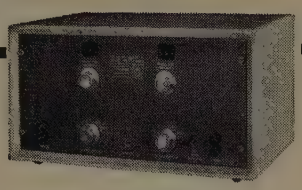
Factories in Los Angeles, Toronto, New Haven. Representatives in principal cities. Address inquiries to Cannon Electric Company, Department L-377, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, California.

NEW ELECTRONIC FILTERS

BAND PASS • REJECTION • SERVO



MODEL **330-A** BAND-PASS

Maximum attenuation greater than 80 db. Unity pass band gain.

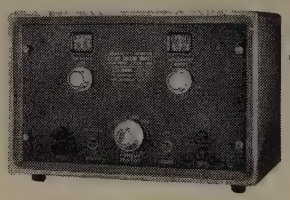
0.02 to 2,000 cps.
24 db/octave each side

MODEL **350-A** REJECTION

Band rejection or sharp null filtering. Unity gain outside rejection region.

EACH MODEL FEATURES

• High and low cut-off frequencies independently tuned over the entire frequency range • Adjustable center frequency • Adjustable band width • 24 db/octave attenuation rates with peaking to reduce corner frequency attenuation • Single scale logarithmic dials • Five decade bands • Internal noise less than 100 microvolts • Maximum input signal 10 volts • Output impedance 500 ohms or 5,000 ohms • Input and output buffer stages • Electronic regulated supplies • Excellent gain and calibration constancy • **Price $450.**

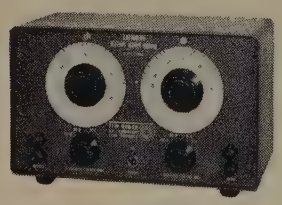


MODEL **340-A** SERVO-DESIGN

0.01 to 100 cps.

For use in the d-c path of a servo loop to obtain either proportional-plus-integral or proportional-plus-derivative correction for experimental determination of optimum filter characteristics.

• Direct reading in frequency and attenuation ratio • Single scale logarithmic dials • Four decade bands • Input and output buffer stages • Electronic regulated supplies • Filament drift cancellation • Good gain and calibration constancy • **Price $350.**



MODEL **310-A** BAND-PASS

Maximum attenuation greater than 60 db. Unity pass band gain.

20 to 200,000 cps.
24 db/octave each side

MODEL **360-A** REJECTION

Band rejection or sharp null filtering. Unity gain outside rejection region.

EACH MODEL FEATURES

• High and low cut-off frequencies independently tuned over entire frequency range • Adjustable center frequency • Adjustable band width • 24 db/octave attenuation rates with peaking to reduce corner frequency attenuation • Single scale logarithmic dials • Four decade bands • Internal noise less than 5 millivolts • Maximum input signal 5 volts • Output impedance 500 ohms • Input and output buffers • Good gain and calibration constancy • Small size • **Price $275.**

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Industrial Engineering Notes

(Continued from page 76A)

Lamb is vice chairman of the Board of Tele King Corporation. He has been a member of the Electronics Board of the National Production Authority and continues as an observer with that group. . . . The General Services Administration has announced **the discovery in Utah of the first native quartz meeting the quality specifications of the defense stockpile.** The agency has contracted to buy the entire output of the new find for the next 12 months. Delivery has already begun. . . . The department of the Army announced that it has awarded General Electric Company a contract for extensive additional microwave equipment for military use. With the new equipment the army plans to improve its communications system overseas and to provide reserve facilities in this country. The system will be installed by the Signal Corps and will supplement present forms of communications. . . . **W. W. Watts, Deputy Defense Production Authority Administrator,** has left his Government post in which he had been serving on a part-time basis to return to his job as vice president in charge of the Engineering Products Division of RCA Victor. He will continue as a consultant to DPA.

NPA News

The National Production Authority has announced the creation of a new priority symbol, "DX," designed to help break bottlenecks in urgent defense production programs. The new DX rating will be applied by NPA to order calling for products, components, or materials other than steel, copper, or aluminum when delay in delivery would jeopardize top-urgency defense programs. . . . The NPA has issued an **order (M-85) providing priority assistance to amateur radio operators.** Order M-85 grants priority assistance to FCC licensed amateur radio stations and stations used by the Civil Air Patrol in obtaining supplies for maintenance and repair, for capital additions to existing stations, and for building new stations. Under the new order, a licensed radio station operator who needs hard-to-get parts may place a delivery order with his supplier, using the allotment symbol MRO to obtain controlled materials and the DO-MRO for components and end equipment. His delivery order must be certified over his signature and show the station call letter. Members of nine major military and emergency networks will each have an annual quota of $200 in rated orders and other "hams" will be limited to $100 of self rated orders. The new order was requested by defense agencies, the Amateur Radio Relay League, and NPA's Electronic Parts and Components Distributors Industry Advisory Committee. . . . **G. W. Henyan, assistant to the vice president of the electronics department of General Electric Company, has succeeded L. H. Niemann as chief of the Components Branch of the NPA Electronics Division.** Mr. Henyan took his new post under E. T. Morris, Jr.

(Continued on page 80A)

THESE ARE SOME OF THE THINGS A WELL-RUN EXPOSITION IN *YOUR* FIELD DOES FOR YOU!

- Brings your prospects to you
- Renews customer contact
- Enables you to actually demonstrate your products
- Establishes contact with people your salesmen can't reach
- Produces inquiries and leads
- Introduces new products quickly
- Opens new markets for you
- Builds sales organization confidence
- Establishes your firm
- Enables you to broaden your sales organization

Seeing is believing

There is no substitute for the actual demonstration of products to your prospective customer.

Buyers are people. They have the normal human instinct of wanting to see what they buy.

Photographs, literature, the most glowing description—by word of mouth or in print—can't quite do the same job of convincing the prospect as a first-hand inspection.

At the exposition which covers your industry or trade, more potential buyers can and do inspect the products of more exhibitors than they could possibly do in any other way in anything like the same time.

That is one of the many reasons why soundly operated expositions continue to grow in popularity and effectiveness for both 'sellers' and 'buyers'.

Are you exhibiting?

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Of The Institute of Radio Engineers

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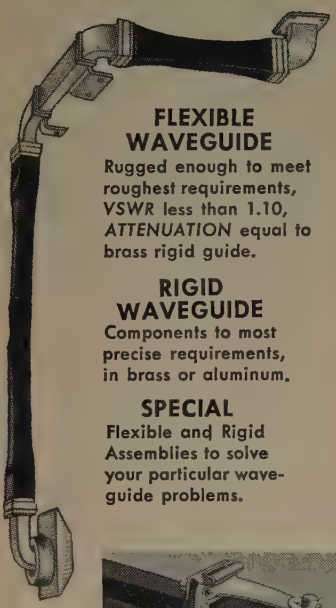
This Advertisement Planned by The National Association of Exhibit Managers

BANK ON Airtron inc.

RIGID and FLEXIBLE WAVEGUIDE COMPONENTS

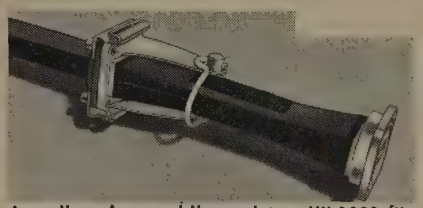


FLEXIBLE WAVEGUIDE
Rugged enough to meet roughest requirements, *VSWR* less than 1.10, *ATTENUATION* equal to brass rigid guide.

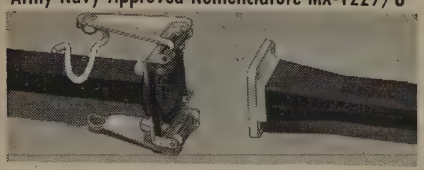
RIGID WAVEGUIDE
Components to most precise requirements, in brass or aluminum.

SPECIAL
Flexible and Rigid Assemblies to solve your particular waveguide problems.

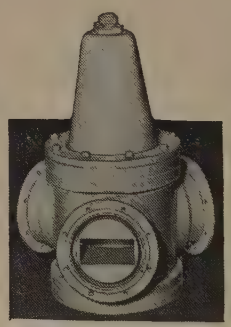
MIXER DUPLEXERS
Built with precision to closest tolerances, and completely tested. Designed to meet your basic requirements and dimensions, or produced from your blueprints.



Army-Navy Approved Nomenclature MX-1229/U

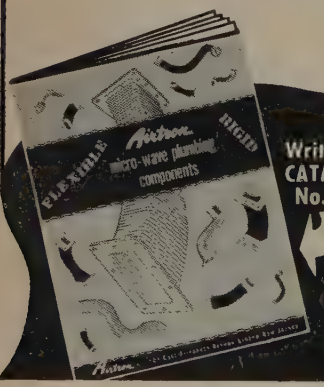


WAVEGUIDE QUICK DISCONNECT
Effective for waveguide junctions of the 1x½ size. Mounts on choke as shown above. Mating part connected or disconnected EASILY and FAST. The clamp is suitable for a pressurized joint up to 30 lbs. at −55° C. under military service.



WAVEGUIDE SWITCHES
A complete line; compact, rugged and suitable for military usage.
VSWR less than 1.10 broadband.
Crosstalk greater than 50 Db.
Speed ½ second or less.
Operation 24 volt DC, 110 Volt AC.
May be specially designed to meet switching problems.

Inquiries are invited.



Write for CATALOG No. 18

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BALTIMORE LOS ANGELES SEATTLE
CHICAGO ST. LOUIS DAYTON

Industrial Engineering Notes

(Continued from page 78A)

Director of the Electronics Division, during the first part of October. Mr. Niemann, who has co-operated with RTMA and the radio-TV industry during his stay at NPA has returned to Sylvania Electric Products Incorporated. He joined the government agency in the fall of 1950, on leave from his company. . . . Conservation of material and the substitution of less critical metals in the production of radio and television receivers will result in a **savings of more than 70,000 tons of critical metals in 1951,** according to a report compiled by the Advisory Council, Material Bureau, of the RTMA Engineering Department. The RTMA estimate, compiled under the direction of chairman L. M. Clement, is based on a production rate this year 20 per cent lower than the 7.4 million TV sets and 14.5 million radios manufactured in 1950. . . . **J. A. Milling, chief of the End Equipment Branch, NPA Electronics Division, has been designated to head the Electronics Production Board** while chairman E. T. Morris, Jr., is in Europe. Mr. Milling, of RCA Service Company Incorporated, has been with NPA since the last of January, 1951.

[1] The data on which these *NOTES* are based were selected, by permission, from *Industry Reports*, issues of September 14, September 21, September 28, October 5, and October 12, published by the Radio-Television Manufacturers' Association, whose helpfulness is greatly appreciated.

RECEIVING MICAS

Standard Brands

CM Types
Silver and Regular Micas
All Capacities
Tolerances 1% and up
Immediate Delivery

Discount Schedule
1-24 ..... 60/10%
25-49 ..... 70%
50 or over 70/10%

Write for latest price schedule.

Mica Condensers Corp.
71 MURRAY STREET • NEW YORK 7, N.Y.
TEL — DIGBY 9-0512

How Bing Crosby's Shavex Speeds up Electric Shaving

Model 5M4 Rectifier Illustrated. Current rating 75MA Max. Input 130V RMS. Max. inv. voltage 300V. Size 1" square.

...THANKS TO VERSATILE SELETRON SELENIUM RECTIFIERS

A wonderful boon to faster whisker removal as smooth as Bing's voice is the Crosby Shavex* which changes household alternating current to D.C., thus boosting the power and speed of any electric razor as much as 40% . . . And built into each unit is a miniature SELETRON Selenium Rectifier No. 5M4 for trouble-free operation.

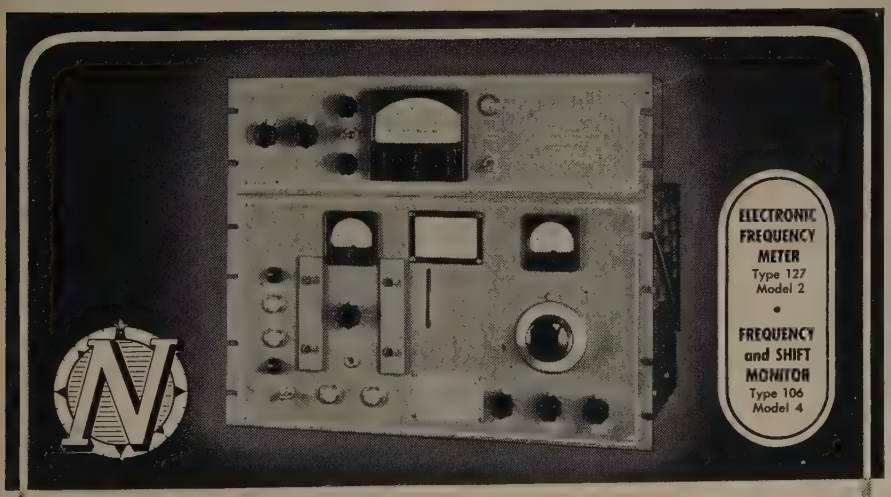
The Shavex is very small, and excessive heating within such a compact enclosure could be a problem. Yet President William H. Burgess of Shavex Division, Electronic Specialty Co., Los Angeles 39, says that extensive temperature tests under full load show SELETRON rectifiers operate much cooler than other rectifiers tested . . . and SELETRON'S reliability has been *confirmed* by successful use of the Shavex under varied conditions of temperature and humidity over a period of several years.

SELETRON builds 'em midget size for radio, TV and other electronic circuits, all the way up to the giant stack assemblies for industrial use. Perhaps the unusual Shavex application may give *you* an idea for putting these versatile selenium rectifiers to work in some other unique spot . . . If so, SELETRON engineers can be of real assistance. Write us today, and request your copy of bulletin 104– E-12

*Reg. T.M. of Electronic Specialty Co.

SELETRON DIVISION
RADIO RECEPTOR COMPANY, Inc.
Since 1942 in Radio and Electronics
Sales Dept.: 251 W. 19th St., New York 11, N. Y. • Factory: 84 N. 9th St., Brooklyn 11, N. Y.

Seletron
T.M. Reg. U.S. Pat. Off.



LABORATORY PRECISION for Communications Monitoring

Speed, sensitivity, widest usefulness, greatest ease of operation, and accuracy and stability—these are the features that make the Northern Radio MONITOR and FREQUENCY METER the most popular monitoring combination in communications. It measures carrier frequency AND shift—during initial setup AND while keying.

The Monitor's stability is better than 2 cycles per megacycle over an ambient temperature range of 0-50° C—using crystals having a temperature coefficient of only 3 parts/million/degree C. Range is 2.5-30 mc with 10 crystal-controlled frequencies (separate panel trimmers for each); use of external oscillator also provided for. Frequency Shift range is 10-10,000 cps. Less than 100 millivolts RF input needed for 2 volts audio output.

The Frequency Meter is specially designed with selectable normal and fast-acting damping factors, permitting frequency measurements of signals WHILE KEYING. Its accuracy is 2% of full scale for the ranges 0-200, 500, 2000, 5000, 20,000 cps.

See the specifications on this outstanding combination in the I.R.E. Directory. For full data on the complete precision-built Northern Radio line, write today for your free latest Catalog P-12.

NORTHERN RADIO COMPANY, inc.
143-145 West 22nd Street
New York 11, N. Y.

Pace-Setters in Quality Communication Equipment

NEW All-Metal... UNIT MOUNTS AND UNIT MOUNTING BASES

MET-L-FLEX

"SEA LEVEL PERFORMANCE AT ANY ALTITUDE"

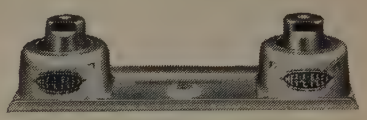
SERIES #7001

#1 AND #2 SIZE CUP TYPE UNIT MOUNTS

SERIES #7002

VIBRATION ISOLATION AND SHOCK PROTECTION FOR AIRBORNE EQUIPMENT

Minimum weight — Maximum structural strength — Complies with all applicable Government specifications — High inherent damping provides stability with shock and over-load capacity — Wide environmental tolerance — Optimum performance under all service conditions. #7001 in 5 load ranges ½ to 10 lbs. — #7002 in 5 load ranges 2½ to 40 lbs.



SERIES #878

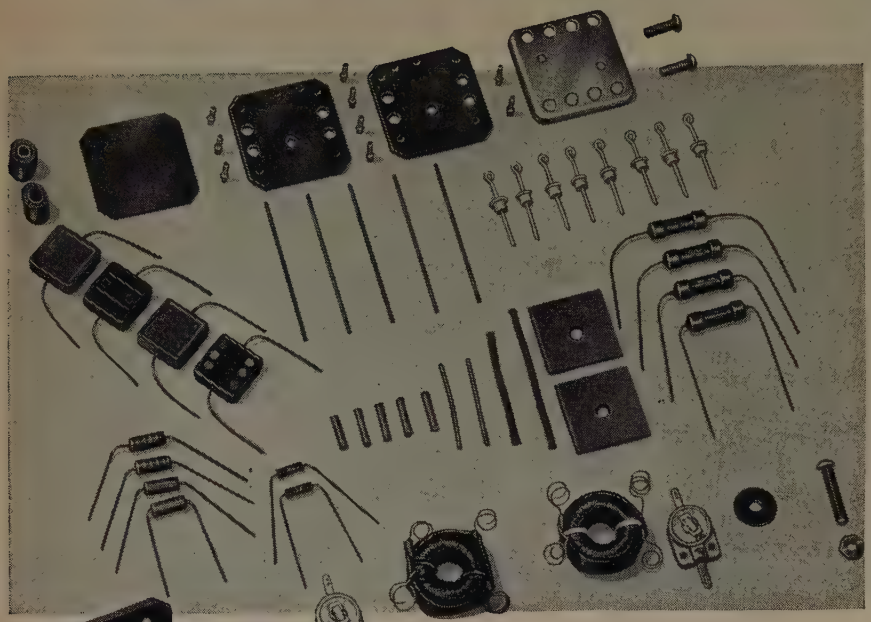
Two #7001 Unit Mounts assembled on common tie plate with bonding jumper — Simplifies mounting and reduces assembly time — Load ranges from 1 to 20 lbs.

SERIES #892

Complete Mounting Bases are available incorporating #7001 or #7002 Unit Mounts. Write for engineering data.

ROBINSON AVIATION INC.
TETERBORO, NEW JERSEY
Vibration Control Engineers

There's More to a Good Filter Than Meets the Eye!



All of these 66 parts are from a single B & W Toroidal-coil type discriminator only 1¾" square by 3½" long exclusive of terminals!

Throughout, the job is one calling for precision components plus a wealth of engineering "know how" in producing and assembling them for maximum performance and effectiveness.

Like all other B & W Special Components, the one illustrated here was designed and produced for a specific application—in this instance a critical military use.

FILTERS

In addition to "tailor-made" discriminators, B & W offers a complete line of performance-proved filters including high-pass, low-pass, band-pass and band suppression types.

TOROIDS

B & W Toroidal Coils of various styles and sizes are available in a wide range of inductance values in open, shielded, potted and hermetically sealed types.

B&W Barker & Williamson, Inc.

237 Fairfield Ave., Upper Darby, Pa.

SECTION MEETINGS

AKRON

"A Time Division Multiplier, A Component of An Electronic Differential Analyzer," by R. V. Baum and C. D. Morrill, Goodyear Aircraft Corporation; September 25, 1951.

"The Magic of Communication," by R. J. Marshall, Ohio Bell Telephone Company; October 16, 1951.

ATLANTA

"High Quality Audio Output Transformers," by Melvin C. Sprinkle, Altec Lansing Corporation; August 27, 1951.

BALTIMORE

"Modern Developments in Cathode Ray Tubes and Their Application," by C. Berkeley, Allen B. Du Mont Laboratories; October 10, 1951.

BEAUMONT-PORT ARTHUR

Inspection by members of FM Industrial Radio-Telephone System; October 17, 1951.

BOSTON

"Visual Communication," by Dr. J. C. R. Licklider, Faculty, Massachusetts Institute of Technology; September 27, 1951.

"Low-Cost High Fidelity Amplifier," by R. R. Noble and F. Mansfield Young, Faculty, Massachusetts Institute of Technology; October 18, 1951.

BUFFALO-NIAGARA

"Radio Astronomy," by Dr. C. R. Burroughs, Director, School of Engineering; September 19, 1951.

CEDAR RAPIDS

"Vibration and Shock Insulation," by G. H. Waite and R. T. Daily, Lord Manufacturing Company; September 18, 1951.

"Printed Circuits," by W. S. Parsons and A. Khouri, Vice-President of Centralab and Head of the Printed Circuit Engineering Group; October 16, 1951.

CHICAGO

"High-Temperature Transformers for Lightweight Requirements," by D. O. Schwennesen, Chicago Transformer Division of the Essex Wire Corporation; September 21, 1951.

CINCINNATI

"Audio Problems in Aircraft Communications," by I. H. Bowker, Wright-Patterson Air Force Base; October 16, 1951.

CLEVELAND

"Seismology and Vibration Analysis," by E. F. Carome, Faculty, John Carroll University; September 27, 1951.

CONNECTICUT VALLEY

"Electronics and Communications Applied to Moder Business Machines," by J. J. Lamb, H. Yellin, and F. B. Hannon, Remington Rand, Inc.; September 20, 1951.

"New Equipment for Audio Analysis," by Mr. Finke, Kay Electric Company; October 18, 1951.

DALLAS-FORT WORTH

"A System for Logging Conductivity and Magnetic Susceptibility in Bore Holes," by C. W. Zimmerman; Magnolia Petroleum Company Field Research Laboratories; September 27, 1951.

DES MOINES-AMES

"Distortions and Causes in Video Recordings," by an A.S.T.P. Student, Iowa State College, and election of officers for forthcoming year; May 25, 1951.

DETROIT

"The Engineer's Future in Radio and Electronic Engineering," Panel Discussion; September 21, 1951.

(Continued on page 84A)

International Selenium Rectifiers

Type W248HS
4960 Volts DC Output
60 ma. Overall length, 13"

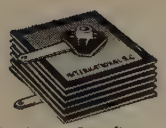
TYPE W-HS-SERIES
60 Milliamperes DC

In 1¼" Phenolic Tube with stud mounting at each end. Circuit-Half-Wave. Overall length varies to 14", depending on DC Output Voltage rating. For many applications for heavier duty and inverse peak suppressor circuits.

PARTIAL LISTING
W-HS SERIES

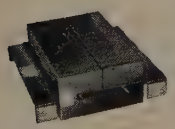
DC Output Voltage	Rectifier Part No.
20	W1HS
60	W3HS
100	W5HS
400	W20HS
800	W40HS
1500	W75HS
2500	W125HS
3500	W175HS
4500	W225HS
6000	W300HS

Over 500 other types



Miniature Rectifiers—from 65 to 1,000 ma.

High Voltage Rectifiers—Cartridge Type



Power Rectifiers—Ratings to 250 KW

Hermetically sealed Cartridge Type Rectifiers

MANUFACTURERS AND DESIGNERS OF

CONTINUOUSLY VARIABLE REGULATED DC SUPPLIES

MODEL D6-DUAL, HEAVY DUTY

- ✓ **DUAL regulated outputs, continuously variable, 0 to 600 volts.**
- ✓ **Maximum current 200 milliamperes each, or 400 combined.**
- ✓ **Regulation better than .5%.**
- ✓ **6.3 volts AC at 10 amperes center-tapped.**
- ✓ **Ripple voltage less than 10 millivolts.**
- ✓ **Stabilized bias supply.**
- ✓ **Request Bulletin 53 for Detailed Information.**

MODELS A3 AND A3A

- ✓ **Continuously variable, 0 to 350 volts.**
- ✓ **Ripple voltages less than 10 millivolts.**
- ✓ **Regulation better than .5%.**
- ✓ **Maximum current 200 milliamperes.**
- ✓ **Stabilized variable bias supply.**
- ✓ **6.3 volts AC at 5 amperes.**
- ✓ **Request Bulletin 52 for Detailed Information.**

Oregon ELECTRONICS MFG. CO.

2232 E. BURNSIDE STREET, PORTLAND 15, OREGON, U.S.A.

LORD MOUNTINGS improve product performance

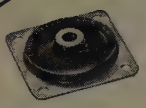
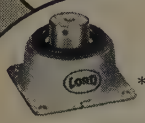


PLATE FORM—STANDARD

Isolate steady-state vibration. Stable, compact—easily installed. Loads 1/2 to 120 pounds per mount.

MULTIPLANE

Isolate vibration from all directions. Light in weight, small in size, they are widely used to mount electronic equipment.



***TEMPROOF**

For Airborne Electronic Equipment

• Designed for use with JAN-C-172A cases. • Exceed AN-E-19 drop test requirements. • Maintain efficiency from −80° to+ 250° F.

*Temperature-proof

LORD Mountings solve many vibration problems. They improve product performance . . . make equipment smoother . . . quieter . . . easier to operate . . . easier to sell. They protect the precision and accuracy of sensitive instruments and controls . . . prolong product life . . . reduce maintenance costs.

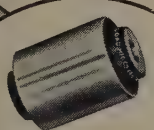
LORD Vibration-Control Mountings have simplified design, reduced weight, speeded assembly, and increased operating efficiency in hundreds of modern products.

To attain these performance improvements, vibration-control should be planned as an integral part of your product. LORD Engineers will assist you to select mountings of proper type, size, and deflection . . . position the mountings for greatest effectiveness.

For improved product sales appeal, bring your vibration problems to LORD . . . Headquarters for Vibration-Control.

PLATE FORM—VERTICAL SNUBBING

Isolate steady-state vibration plus severe shock. Loads up to 610 pounds per mount.



TUBE FORM—STANDARD

For steady-state vibration and occasional shock. Have great radial stability. Loads from ½ to several thousand pounds.

FLEXIBLE COUPLINGS—F. H. P.

Have exceptional torsional softness . . . accommodate parallel and angular misalignment. Ratings from 1/50 to 1 hp.

FLEXIBLE COUPLINGS—M. H. P.

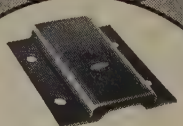
Have exceptional torsional softness to isolate torsional vibration. Removable flexing elements allow installation without moving hubs. Ratings to 100 hp at 1750 RPM.

TUBE FORM—VERTICAL SNUBBING

Isolate steady-state vibration and severe shock. Recommended for mobile equipment.

CHAN-L-MOUNTS

Ready to use—easy to install. Isolate steady-state vibration and occasional shock. Extremely soft and sturdy, they give superior isolation.



SHOCKMOUNTS

Isolate noise and vibration from punch presses, looms, printing presses, etc. Neoprene resists attack by oil and grease. Load ratings up to 7500 pounds per mount.

LORD

VIBRATION-CONTROL MOUNTINGS AND BONDED-RUBBER PARTS

LORD MANUFACTURING CO., ERIE, PA.

SECTION MEETINGS

(Continued from page 82A)

"The New Baldwin Photo-Electric Organ," by J. F. Jordan, Baldwin Piano Company; October 4, 1951.

EVANSVILLE-OWENSBORO

"Electronic Trends of Tomorrow," by Dr. J. D. Ryder, Faculty, Illinois University; October 12, 1951.

FORT WAYNE

"Analog Computers," by Dr. J. D. Ryder, University of Illinois; October 3, 1951.

HAWAII

"The Doherty Amplifier," by M. Vittum; Federal Communications Commission; September 12, 1951.

KANSAS CITY

"Electronic Biological Instruments," by Dr H. W. Shirer, Faculty, University of Kansas; September 18, 1951.

"Nuclear Instrumentation," by Dr. L. W. Seagondollar, University of Kansas; October 16, 1951.

LOS ANGELES

Address by I. S. Coggeshall, President, Institute of Radio Engineers; August 20, 1951.

"Strategy in the Theory of Games," by Dr. E. W. Paxson, Rand Corporation, and "A Very Low-Frequency Function Generator," by Mr. R. Morgan, Neely Enterprises; September 11, 1951.

LOUISVILLE

"Principles of Electronic Tube Testing," by H. Rockwell, Rockwell Engineering Company; October 12, 1951.

MIAMI

"A Simulated Telephone Line, Its Theory and Construction," by Mr. P. H. McBride, Student, University of Miami; June 22, 1951.

NEW MEXICO

"Telemetering System for a 12 MEV Electrostatic Accelerator," by C. W. Johnstone and J. F. Kalbach; August 25, 1951.

"Air Defense of the Albuquerque Area," by Lt. Col. Glen E. Mann; September 29, 1951.

NEW YORK

"Recent Developments in Transistors and Related Devices," by Dr. J. S. Saby, General Electric Company; September 12, 1951.

NORTH CAROLINA-VIRGINIA

"Simple Analysis of Transient Response of Amplifiers," by Dr. G. B. Hoadley, Faculty, North Carolina State College; September 21, 1951.

OKLAHOMA CITY

First official meeting and election of officers for the Oklahoma City Section; October 5, 1951.

OTTAWA

"Television in Canada," by J. Alphonse Ouimet, Canadian Broadcasting Company; October 11, 1951.

PHOENIX

"Micro-Wave Communication System," by C. Meyer, Motorola Research Laboratory; September 28, 1951.

PRINCETON

"Automatic Control with Relays," by W. Keister, Bell Telephone Laboratories, Inc.; October 11, 1951.

ST. LOUIS

"Plastic Embedment of Electronic Equipment," by D. G. Heitert, Emerson Electric Manufacturing Company; September 27, 1951.

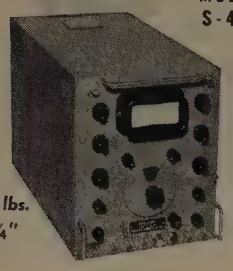
General Inspection and Open House, New Research Building, Central Institute for the Deaf, Dr. R. Benson and Dr. S. R. Silverman, Hosts; October 18, 1951.

(Continued on page 86A)

THE SAR PULSESCOPE

BY WATERMAN

MODEL S-4-A



Weight 31.5 lbs.
9⅛" x 11¼"
x 17¼"

Another example of WATERMAN pioneering, a compact, portable instrument for precision pulse measurements adaptable for all electronic work, including radar and TV. S-4-A SAR PULSESCOPE will portray all attributes of the pulse; such as shape, amplitude, duration and time displacement. In S mode of operation, the unit functions as a wide band oscilloscope, with optional video delay, in either repetitive or triggered sweep conditions. In A mode of operation the unit functions as a precision time measuring device, with internal crystal controlled markers available for self calibration. In R mode of operation a desired small segment of A Sweep is expanded to fill the face of the tube for detailed observation.

Video Amplifier band pass up to 11 mc . . . optional Video delay 0.55 μs . . . Pulse rise and fall time better than 0.07 μs . . . Video sensitivity of 0.5 p to p/inch . . . S Sweep 80 cycles to 400 KC either triggered or repetitive . . . A Sweep 1.2 μs to 12,000 μs . . . R Delay 3 μs to 10,000 μs . . . Directly calibrated on a precision dial . . . R Pedestal (or sweep) 2.4 μs to 24 μs . . . A & R Sweep triggers available externally . . . Internal crystal markers of 10 μs and 50 μs . . . Built in precision amplitude calibration . . . Operates on 50 to 1000 cycles at 115V AC.

WATERMAN PRODUCTS CO., INC.

PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

WATERMAN PRODUCTS INCLUDE:

S-5-A LAB	PULSESCOPE
S-10-B GENERAL	POCKETSCOPE
S-11-A INDUSTRIAL	POCKETSCOPE
S-14-A HIGH GAIN	POCKETSCOPE
S-14-B WIDE BAND	POCKETSCOPE
S-15-A TWIN TUBE	POCKETSCOPE

Also RAYONIC Cathode Ray Tubes
RAKSCOPES and other equipment

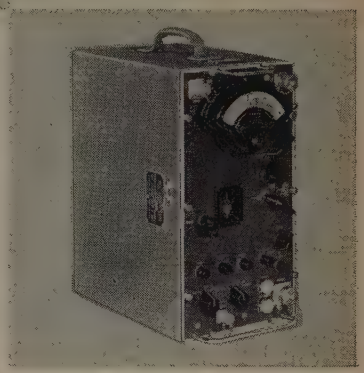
WATERMAN PRODUCTS

STANDARD *Radio Interference and Field Intensity* MEASURING EQUIPMENT

Complete Frequency Coverage -- 14kc to 1000mc!

NM - 10A VLF

14kc to 250kc
Commercial Equivalent of AN/URM-6.
Very low frequencies.



HF **NM - 20A**

150kc to 25mc
Commercial Equivalent of AN/PRM-1. Self-contained batteries. A.C. supply optional. Includes standard broadcast band, radio range, WWV, and communications frequencies.

NMA - 5A VHF

15mc to 400mc
Commercial Equivalent of TS-587/U.
Frequency range includes FM and TV Bands.

VHF **NM - 50A**

375mc to 1000mc
Commercial Equivalent of AN/URM-17.
Frequency range includes Citizens Band and UHF color TV Band.

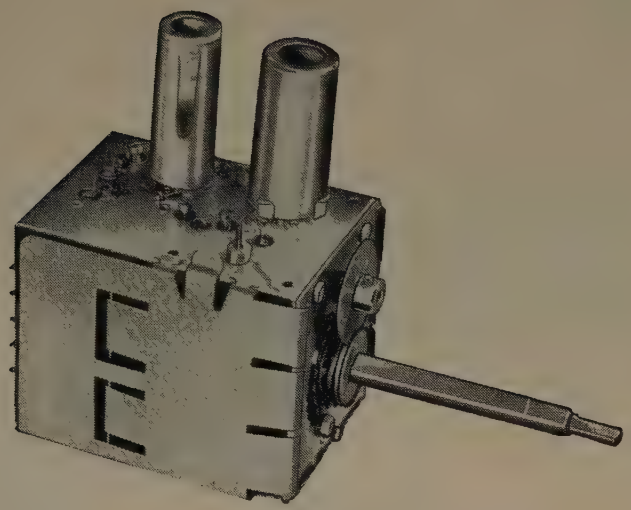
These instruments comply with test equipment requirements of such radio interference specifications as JAN-I-225a, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a MIL-I-6722 and others.

STODDART AIRCRAFT RADIO CO.

6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294

Designed for

UHF



The NEW TARZIAN TT-16 Tuner,

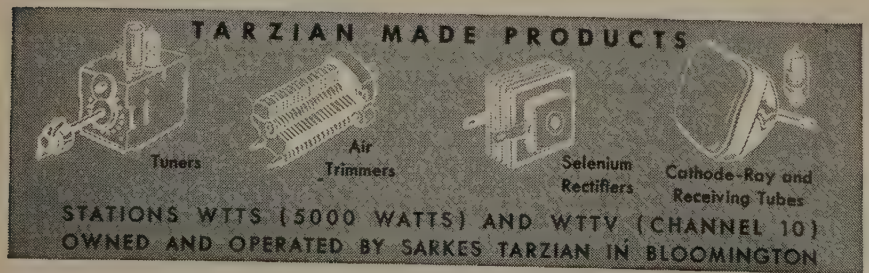
now in production, is the complete answer to future UHF problems.

● The Tarzian TT-16 Tuner is the logical approach to UHF. The TT-16 is a VHF Tuner which will accept UHF stations—through a full-range UHF Tuner—without loss of present VHF channels.

Full range (70 Channel) coverage is provided. Forward-looking manufacturers are asked to write or call for complete information.

SARKES TARZIAN, Inc.

Tuner Division **Bloomington, Indiana**


TARZIAN MADE PRODUCTS
Tuners
Air Trimmers
Selenium Rectifiers
Cathode-Ray and Receiving Tubes
STATIONS WTTS (5000 WATTS) AND WTTV (CHANNEL 10)
OWNED AND OPERATED BY SARKES TARZIAN IN BLOOMINGTON

SECTION MEETINGS

(Continued from page 84A)

SALT LAKE

"Electronic Trends of Tomorrow," by Dr. J. D. Ryder, Faculty, University of Illinois; September 18, 1951.

SAN ANTONIO

"Radiometric Instruments; Theory and Operation," by E. O. Richey, Faculty, School of Aviation Medicine, Randolph Field, Texas; October 4, 1951.

SAN DIEGO

"Broadband Radio Relay System," by E. H. Schreiber, Pacific Telephone and Telegraph Company; October 9, 1951.

SYRACUSE

"Electronic Equipments Abroad," by A. Coumont, International General Electric Company; October 4, 1951.

TOLEDO

Three reels of technical film shown and a discussion of coming programs and papers and business for the 1951–52 season; September 20, 1951.

TORONTO

"Picture Tube and Receiving Tube Development and Manufacture," by J. F. Hinds and F. C. Carey, Radio Valve Company of Canada Ltd.; October 1, 1951.

TULSA

"Introduction to Nucleonics," by D. L. Chestnut, General Electric Company; October 5, 1951.

TWIN CITIES

"Electronic Trends of Tomorrow," by Dr. J. D. Ryder, University of Illinois; September 25, 1951.

WASHINGTON, D. C.

"Transistors and Related Devices," by Dr. J. S. Saby, General Electric Company; August 16, 1951.

"Magnetic Amplifiers—in Practice and Theory," by Dr. R. A. Ramey, Naval Research Laboratory; October 8, 1951.

SUBSECTIONS

BINGHAMTON

"Electronically Supervised Clock Systems," by W. Webb, International Business Machines Company; September 11, 1951.

HAMILTON

"Electronics in Europe," by J. T. Thwaites, Canadian Westinghouse Company, Ltd.; September 17, 1951.

MID-HUDSON

"Recent Color Television Engineering Developments," by Dr. R. M. Bowie, Sylvania Electric Product Company; September 11, 1951.

MONMOUTH

"Recent Trends in Long-Range Communications," by M. G. Crosby, Crosby Laboratories, Inc.; September 26, 1951.

NORTHERN NEW JERSEY

"The Magic of Relays," by W. Keister, Bell Telephone Laboratories, Inc.; September 12, 1951.

PALO ALTO

"Recent Developments in the Antenna Research Program at the Stanford Research Institute," by Dr. J. V. N. Granger, Stanford Research Institute; September 26, 1951.

ROME

"The Sampling Feedback System," by J. R. Ragazzini, Faculty, Columbia University; September 10, 1951.

"Modern Mathematics in Circuit Techniques from Audio to Microwaves," by Dr. E. Weber, Microwave Research Institute; October 8, 1951.

Kenyon

TRANSFORMERS

For all

ARMY
NAVY

SPECIFICATIONS

✦

There's a Kenyon quality transformer to meet almost any standard or special application.

RADAR
BROADCAST
JAN APPLICATIONS
ATOMIC ENERGY EQUIPMENT
SPECIAL MACHINERY
AUTOMATIC CONTROLS
EXPERIMENTAL LABORATORIES

For full details—
Contact Kenyon today

Kenyon
Transformer Co., Inc.

840 Barry St. New York 59, N.Y.

ALABAMA POLYTECHNIC INSTITUTE, IRE BRANCH

General meeting; October 15, 1951.

BUCKNELL UNIVERSITY, IRE-AIEE BRANCH

"Aims and Purposes of the Student and National Branches of IRE and AIEE," by B. Bueffel, Faculty, Bucknell University; October 10, 1951.

UNIVERSITY OF CALIFORNIA, IRE-AIEE BRANCH

"Industrial Applications of Atomic Energy," by Professor L. Reukema, Faculty, University of California; October 4, 1951.

CASE INSTITUTE OF TECHNOLOGY, IRE BRANCH

Organization meeting; September 28, 1951.

CLARKSON COLLEGE OF TECHNOLOGY, IRE BRANCH

"Why You Should Join the IRE," by Dr. F. Record, Faculty, Clarkson College of Technology; September 26, 1951.

UNIVERSITY OF COLORADO, IRE-AIEE BRANCH

"Lightning Protection of Power Lines," by F. A. Eastom, Head of the Electric Power Laboratory, University of Colorado; October 3, 1951.

"Atomic Energy," by Dr. F. Rohrman, Research Department, University of Colorado; October 17, 1951.

UNIVERSITY OF CONNECTICUT, IRE-AIEE BRANCH

"Transistors," by Dr. H. J. Reich, Faculty, Yale University; October 11, 1951.

COOPER UNION SCHOOL OF ENGINEERING, IRE BRANCH

Election of officers; September 24, 1951.

UNIVERSITY OF DETROIT, IRE BRANCH

"Digital and Analogue Computers," by Mrs. M. Goodwin, Holley Carburetor Company; E. A. Baldini, Detroit Edison Company; J. Chancellor, I.B.M. Company; and P. T. Nims, Chrysler Corporation; September 26, 1951.

DREXEL INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

"Color Television," by R. Moore, Section Engineer, Philco Corporation; October 4, 1951.

FENN COLLEGE, IRE BRANCH

"Television Networks," by O. Henderson, Engineer, Ohio Bell Telephone Company; September 28, 1951.

UNIVERSITY OF ILLINOIS, IRE-AIEE BRANCH

"Mobile Radio," by R. V. Dondanville, Commonwealth Edison Company; September 25, 1951.

STATE UNIVERSITY OF IOWA, IRE BRANCH

"My Practical Experience at Westinghouse, Pittsburgh," by K. Nicodemus, and "My Practical Experience at Turner Company, Cedar Rapids," by W. Bratsberg, Students, State University of Iowa; October 3, 1951.

LAFAYETTE COLLEGE, IRE-AIEE BRANCH

"The AIEE," by D. Campbell, Vice-Chairman, Lehigh Valley Section of AIEE; September 25, 1951.

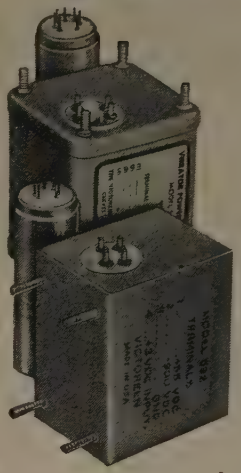
UNIVERSITY OF LOUISVILLE, IRE BRANCH

Business meeting; October 10, 1951.

MANHATTAN COLLEGE, IRE-AIEE BRANCH

"Counter Circuits—Scale of two—to Decade," by T. P. Canavan, Faculty, Manhattan College; October 10, 1951.

(Continued on page 88A)



. . . four newcomers to their catalog of quality components and instruments for the electronic and radiation-measurement fields.

Victoreen has developed two high-efficiency, light-weight vibrator power supplies for use with battery-operated portable equipment such as Geiger counters, photo-multipliers, and electronic equipment requiring a 900 volt supply. These compact units have been potted and hermetically sealed to make them reliable and rugged. They contain regulator circuits to stabilize their output and have a plate voltage output to operate electronic circuits. Net weight is only one pound.

• THE MODEL 517 VIBRATOR POWER SUPPLY operates from 4.5 volts of battery and supplies +900 volts at 5 microamps and +55 volts at 0.25 ma.

• THE MODEL 532 VIBRATOR POWER SUPPLY operates from 3.0 volts of battery and supplies −900 volts at 15 microamps and +55 volts at 0.25 ma.

The precision vibrators which are used in these power supplies are available separately. They have been mounted in sponge rubber and hermetically sealed, and are available for such applications as high-voltage power supplies, portable Geiger counters, scintillation counters, and portable radios. These plug-in units weigh only 2½ ounces.

• THE MODEL 531 VIBRATOR is designed to operate from a 1.5 or 1.3 volt battery and requires a minimum of 18 milliwatts driving power.

• THE MODEL 542 VIBRATOR is also an 18 milliwatt unit but designed for operation in series with the primary of a transformer and from a 1.5 to 6 volt battery.

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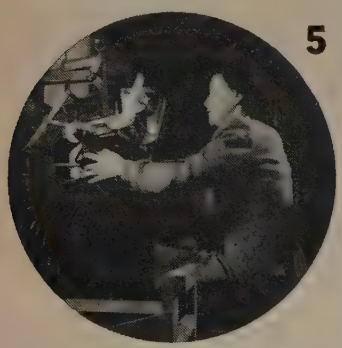

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STUDENT BRANCH MEETINGS

(Continued from page 87A)

UNIVERSITY OF MARYLAND, IRE-AIEE BRANCH

Talks by J. Hirsefield, W. North, and H. Gordon, Students, University of Maryland; October 3, 1951.

MICHIGAN COLLEGE OF MINING AND TECHNOLOGY IRE-AIEE BRANCH

Business meeting; October 16, 1951.

MICHIGAN STATE COLLEGE, IRE-AIEE BRANCH

Speech on the AIEE by I. R. Baccus, Faculty, Michigan State College; October 4, 1951.

UNIVERSITY OF MICHIGAN, IRE-AIEE BRANCH

"Opportunities for Engineers in Industry," by F. Von Voightlander, Sperdi-Faraday Corporation; October 10, 1951.

UNIVERSITY OF MISSOURI, IRE-AIEE BRANCH

"The Electrical Engineering Curriculum at the University of Missouri," by C. M. Wallis, Faculty, University of Missouri; October 11, 1951.

COLLEGE OF THE CITY OF NEW YORK, IRE BRANCH

Film, "Resistive Welding," and general meeting; October 18, 1951.

NEW YORK UNIVERSITY (EVENING DIVISION), IRE-AIEE BRANCH

Business meeting; October 5, 1951.

NORTHEASTERN UNIVERSITY, IRE-AIEE BRANCH

"The Principles of Pulse Radar," by Professor M. Essigmann, Air Force Project at Northeastern University; September 20, 1951.

"The Development of the Niagara System," by C. A. Powell, Massachusetts Institute of Technology; September 25, 1951.

UNIVERSITY OF NOTRE DAME, IRE-AIEE BRANCH

Film, "How Distribution Transformers Are Made," and general meeting; September 19, 1951.

PENNSYLVANIA STATE COLLEGE, IRE-AIEE BRANCH

Film, "Atomic Energy," and talk, "Outside of the Classroom—What?", by E. B. Stavely, Dean, Pennsylvania State College; September 27, 1951.

Film, "Electrical Proving Grounds," and general meeting; October 11, 1951.

UNIVERSITY OF PENNSYLVANIA, IRE-AIEE BRANCH

Business meeting; October 3, 1951.

PRATT INSTITUTE, IRE BRANCH

Business meeting; September 26, 1951.

PRINCETON UNIVERSITY, IRE-AIEE BRANCH

Discussion on summer employment by R. Pierce, R. Hartel, J. Seward, B. Gough, T. Worthington, J. Gray, and B. Starret, Students, Princeton University; October 4, 1951.

UNIVERSITY OF RHODE ISLAND, IRE-AIEE BRANCH

General meeting; May 24, 1951.
Election of officers; September 20, 1951.

RUTGERS UNIVERSITY, IRE-AIEE BRANCH

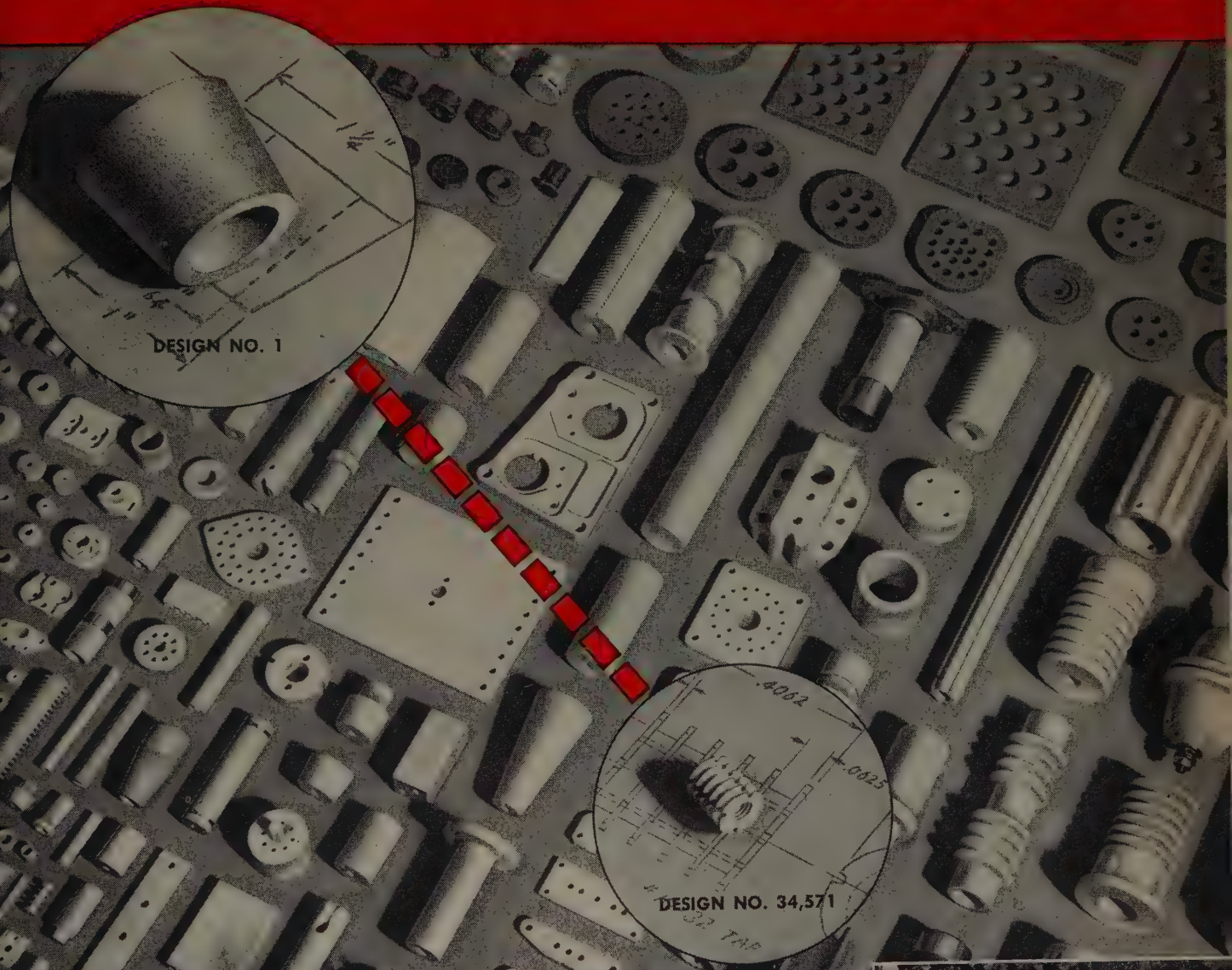
Business meeting; September 25, 1951.

SAN DIEGO STATE COLLEGE, IRE BRANCH

"Television Transmitter," by J. Duncan, Engineer, KFMB-TV; October 11, 1951.

(Continued on page 90A)

34,571 designs + 50 years of specialized experience ARE AVAILABLE IN ALSIMAG®



On any problem involving technical ceramics, the cooperation of our engineers is available on request. Their half a century of specialized experience has enabled them to help solve many different design problems. Hand made experimental or test designs can be made quickly and at reasonable cost. When the design has been tested and perfected, quantity production is now more quickly available from our new plants which are in production.

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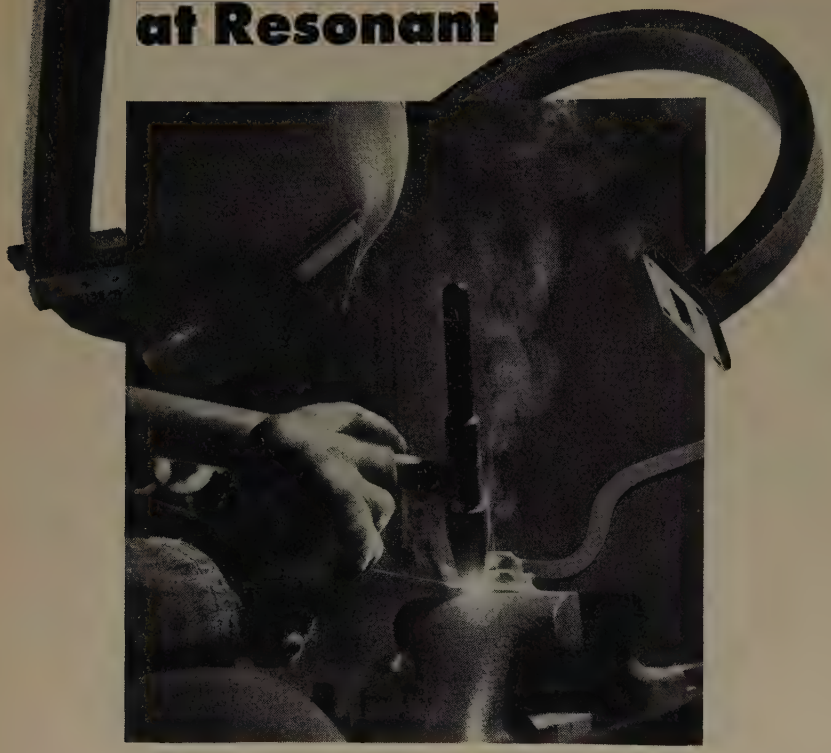
Welding Magnesium Waveguide at Resonant



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STUDENT BRANCH MEETINGS

(Continued from page 88A)

UNIVERSITY OF SOUTH CAROLINA, IRE-AIEE BRANCH

General meeting; October 4, 1951.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY, IRE BRANCH

General meeting; September 19, 1951.
General meeting; October 3, 1951.

SOUTHERN METHODIST UNIVERSITY, IRE-AIEE BRANCH

"Atomic Power Generation," by D. L. Chestnut, General Electric Company; October 15, 1951.

UNIVERSITY OF TEXAS, IRE-AIEE BRANCH

"Advantages of Student Membership in Professional Societies," by R. R. Krezdorn, Faculty, University of Texas; October 15, 1951.

TUFTS COLLEGE, IRE-AIEE BRANCH

General meeting and films, "Natural Waters," "Jet Propulsion," and "Light"; October 10, 1951.

VIRGINIA POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH

Address on "Purposes of AIEE and IRE," by W. A. Murray, Faculty, Virginia Polytechnic Institute; September 24, 1951.

Talks on summer employment by F. W. Field, R. W. Klimpel, and D. P. Lamorte; October 2, 1951.

General meeting; October 9, 1951.

WORCESTER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH

General meeting; October 22, 1951.

MEMBERSHIP

The following transfers and admissions were approved and will be effective as of December 1, 1951:

Transfer to Senior Member

Barasch, M. V., 2176 Monte Vista St., Pasadena 8, Calif.
Biele, R. J., 306 Strathmore Dr., Syracuse, N. Y.
Born, W. T., 2607 N. Boston Pl., Tulsa 6, Okla.
Clark, M. E., 118 N. Woodland Dr., Liverpool, N. Y.
Davie, M. C., Jr., 3132 Eighth St., N., Arlington 1, Va.
Espersen, G. A., 65 Bellewood Ave., Dobbs Ferry, N. Y.
Henrici, C. R., 1058 Daniels St., N.E., Cedar Rapids, Iowa
Hoff, K., Blokk 17, Snippen, Smestad pr Oslo, Norway
Humiston, H. A., 26-D Oak Grove Dr., Baltimore 20, Md.
Jensen, R. C., Cold Springs Rd., Baldwinsville, N. Y.
Leas, J. W., 2312 N. Wakefield St., Arlington 7, Va.
McClean, J. F., Box 291, Goshen, N. Y.
McVay, M. S., 504 S. Broadway, Urbana, Ill.
Miles, R. C., 70 Greenway, E., North Shore Hills, New Hyde Park, N. Y.
Mitchell, R. M., 357 Garden Dr., S.E., Cedar Rapids, Iowa
O'Hare, E. F., 8325 Delcrest Dr., University City 24, Mo.

(Continued on page 92A)

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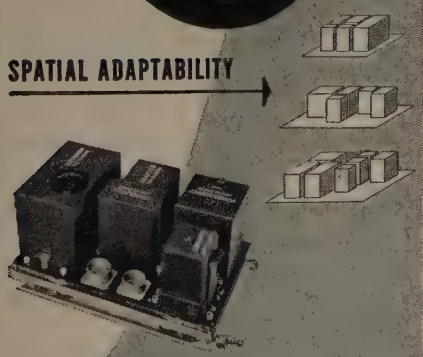

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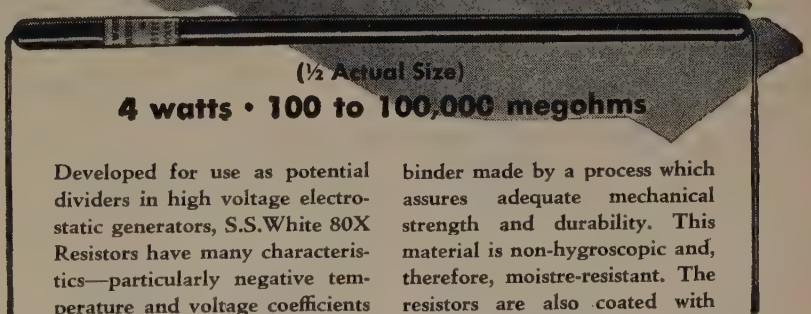
The new S.S.WHITE 80X
HIGH VOLTAGE RESISTOR



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4 watts • 100 to 100,000 megohms

Developed for use as potential dividers in high voltage electrostatic generators, S.S.White 80X Resistors have many characteristics—particularly negative temperature and voltage coefficients—which make them suitable for other high voltage applications.

They are constructed of a mixture of conducting material and binder made by a process which assures adequate mechanical strength and durability. This material is non-hygroscopic and, therefore, moistre-resistant. The resistors are also coated with General Electric Dri-film which further protects them against humidity and also stabilizes the resistors.

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It gives complete information on S.S.White resistors. A free copy and price list will be sent on request.

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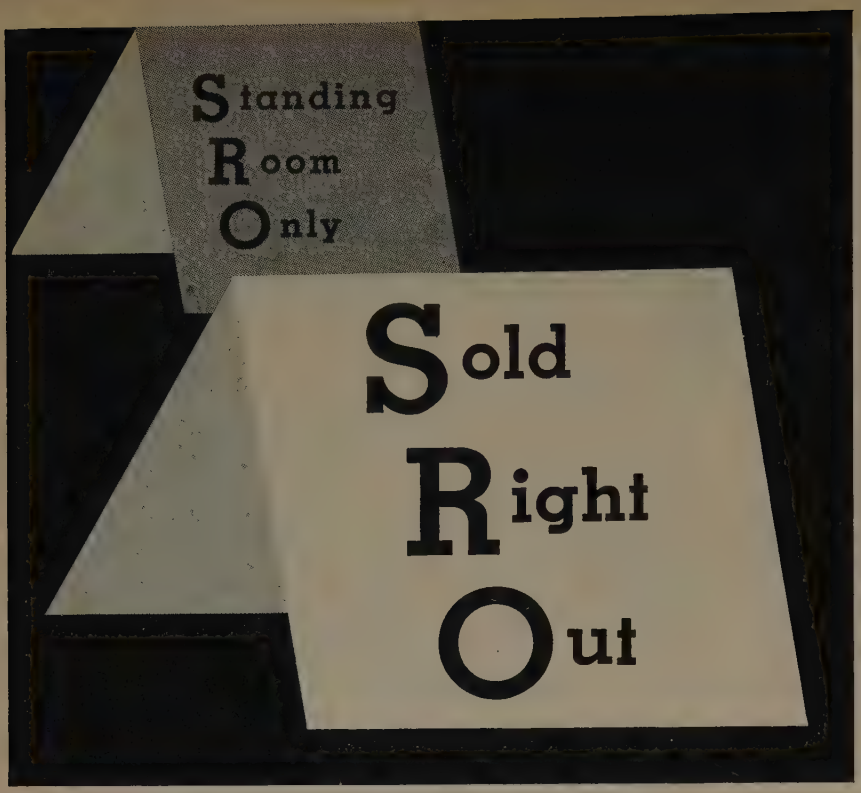

We're sorry, but we think it's only fair to tell possible new customers our Standing Room Only sign must be changed to Sold Right Out!

The design and production facilities of our microwave department are now taken over by the increasing requirements of our present customers. Because of our responsibility to them, this situation may continue quite a while.

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MEMBERSHIP

(Continued from page 90A)

Pease, M. C., III, 36 Coulton Park, Needham 92, Mass.
Pratt, A., 14607 Hesby St., Sherman Oaks, Calif.
Reitz, L. P., Jr., 4016 Via Largavista, Palos Verdes Est., Calif.
Root, C. S., 3801 N. Washington Rd., Fort Wayne 8, Ind.
Swanson, E. R., 5827 Madden Ave., Los Angeles 43, Calif.
Yeh, C., Electrical Engineering Department, University of Kansas, Lawrence, Kans.

Admission to Senior Member

Bhate, A. G., National Carbon Co. (India) Ltd., 18A Brabourne Rd., Calcutta 1, India
Franz, K. O., Rosario de Sta. Fe 673, San Isidro FCNGBM, Argentina
Hester, F. A., 149 W. 12 St., New York 11, N. Y.
Holmes, E. A., III, 616 N. Magnolia Ave., Whittier, Calif.
Prihar, Z., Posts, Telegraphs, Telephones and Radio, Jerusalem, Israel.
Romig, H. G., Hughes Aircraft Co., Florence Ave. & Teale St., Culver City, Calif.
Schenck, H. H., Caixa Postal 709, Rio de Janeiro, Brazil

Transfer to Member

Ankele, E. T., Jr., 6623 Prosper, Dallas, Tex.
Archambault, G. T., 203 Youville Sq., Montreal, Que., Canada
Astrahan, M. M., 6 Cedar Lane, Poughkeepsie, N. Y.
Bennison, G. K., Box 1116, Haselton Br., Rome, N. Y.
Carson, R. S., 1829 Hale Ave., Fort Wayne 6, Ind.
Crone, J. L., 3520 E. Anderson Ave., Albuquerque, N. Mex.
Fullerton, R. D., 1645 Mussula Rd., Towson 4, Md.
Hiltpold, L. E., 8406 Glenbrook Dr., Houston 17, Tex.
Kahn, L. R., 46 W. 95 St., New York 25, N. Y.
Karcher, E. R., 3759 Ray St., San Diego 4, Calif.
Linder, W. J., Wildcat Rd., R.R. 1, Tipp City, Ohio
Mims, A. J., 3348 Sanders, Houston 4, Tex.
Wadel, L. B., 3905 Centenary, Dallas 5, Tex.
Webb, H. E., Box 543, Rome, N. Y.

Admission to Member

Agress, M. C., 852 Monroe St., Brooklyn 21, N. Y.
Arce, H. H., Edificio Jorge Garces, Oficina 406, Bogota, Colombia
Atkins, G. T., 571 Nightingale Dr., Miami Springs, Fla.
Bailey, J. S., 1340 Oak St., Syracuse, N. Y.
Bennett, R. S., The B.S.A. Group Research Centre, Whiston Grange, Moorgate, Rotherham, England
Bicknese, F. H., 144–24A Village Rd., Jamaica 2, L. I., N. Y.
Burnett, J. H., 92 Overlook Rd., Upper Montclair, N. J.
Charpentier, D. E., 790 Franklin Blvd., Cleveland 24, Ohio
Coburn, W. K., 14 Coolidge Ave., Cambridge 38, Mass.
Dill, C. L., Jr., 22500 Gaukler St., St. Clair Shores, Mich.
Drake, E. C., 125 Osage Ave., Cold Spring, Ky.
Finison, H. J., Armour Research Foundation, Technology Center, Chicago 16, Ill.
Gordon, J. R., 777 Austin Lane, Winston-Salem 5, N. C.
Greatbatch, W. H., Jr., R.D. 13, Box 206, Indianapolis, Ind.
Hill, D. A., 17319 Magnolia Blvd., Encino, Calif.
Kelly, E. P., Jr., 1620 E. 55 St., Chicago 15, Ill.
Olson, C. V., 438 Nassau St., Princeton, N. J.

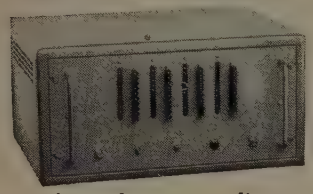
(Continued on page 94A)

ELECTRONIC INSTRUMENTATION

for LABORATORY *or* PRODUCTION LINE!

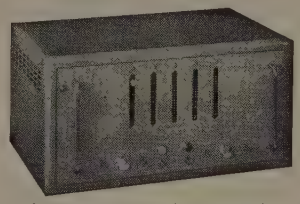
DECIMAL COUNTING UNIT, MODEL 700 is a direct reading electronic counter capable of operating at speeds up to 30,000 counts per second. Digits from 0 to 9 are presented on illuminated front panel. Electrical reset to zero. Plug-in octal mounting for easy interchangeability. The counter operates on input pulse of 100 volt neg. with 2 microsec. max. rise time. Output will drive following unit in cascade. Dimensions 1⅜" x 5" x 5¼". Wt. 12 oz. Other models to a million counts per second.

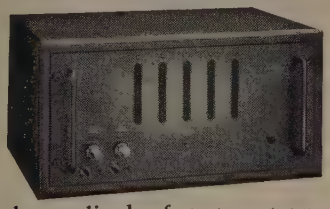
ELECTRONIC COUNTER, MODEL 10 was developed to meet the need for a rugged industrial counter operating at speeds up to 6000 counts per minute. Total count is displayed on the Decimal Counting Unit and the mechanical register to a maximum capacity of 9,999,999. Unit may be operated from closing contacts, photocell, or any means that will supply a positive potential of at least 3 volts. All circuitry moisture and fungus proofed. Unit is available in a variety of vapor-proof and explosion-proof housings to meet individual requirements. Dimensions 6¼" x 7¼" x 6½". Weight approximately 6 lbs.



PRESET COUNTER consists of a series of scale-of-10 electronic counting units each in parallel with a 10-position push-button switch. This instrument accepts counts in the conventional manner at rates up to 10,000 cps. Any number from 0 to maximum capacity may be preset merely by depressing appropriate push-button in each column. Upon reaching the preset count, the unit supplies an output pulse to drive a register, close a gate, divert a production line or perform any other desired function. It then resets to 0 and recycles automatically. Available in any desired capacity.

EVENTS PER UNIT TIME METER, MODEL 554 will automatically count and display the number of events that occur during a precise one second interval at rates up to 100,000 events per second. Accuracy is ± one event. Will operate either manually or automatically to count any mechanical, electrical, or optical occurrences, regularly or randomly spaced, that can be converted into changing voltages. Instrument counts for one second and displays the results on illuminated five-digit panel. Will recycle continuously on automatic operation. Convenient test switch permits 2 second self-check of entire unit. Dimensions 20¾" x 10½" x 15". Weight approximately 68 lbs.





TIME INTERVAL METER, MODEL 510 provides a direct reading of elapsed time between any two events in the range of 0.000010 to 1.00000 seconds. Accuracy is ± 10 microseconds. Any occurrences that can be translated into changing voltages may be so timed. Timing may be started and stopped by independent voltages, the polarity of which may be selected by means of toggle switches. Sensitivity control permits selection of the amplitude of start or stop voltages at optimum level for elimination of interference. Dimensions 20¾" x 10½" x 15". Weight approximately 58 lbs.

SINGLE/DOUBLE PULSE GENERATOR MODEL 903 is a general purpose laboratory instrument that supplies either single or paired pulses individually variable in amplitude, width and polarity. Pulse spacing is continuously variable from 0 to 10 microseconds, pulse width from 0.10 to 1.6 microseconds and pulse amplitude from 200 volts maximum negative and 50 volts maximum positive for 1000 ohm load, and 10 volts maximum negative and 50 volts maximum positive for 50 ohm load. Single or double pulses are available through separate panel connectors. Repetition rate internally controlled 1 to 1000 cps. Push-button control single cycle. External signal control for any rate up to 1000 cps.

These are basic descriptions of representative standard instruments. A variety of modifications, both standard and special, are available to meet specific requirements. For complete details write Dept. P.

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TYPE BH6A RANGE: 1.4 - 75.0 mc

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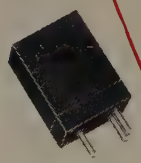

TYPE AR23W: RANGE: 0.080 - 0.19999 mc Supplied per Mil type CR-15; CR-16; CR-29; CR-30 when specified.

TYPE MC9: RANGE: 1.0-10.0 mc Supplied per Mil type CR-5; CR-6; CR-8; CR-10 when specified.

TYPE SR5A RANGE: 2.0-15.0 mc Supplied per Mil type CR-1A when specified.

TYPE TCO-1 Temperature Control Oven.

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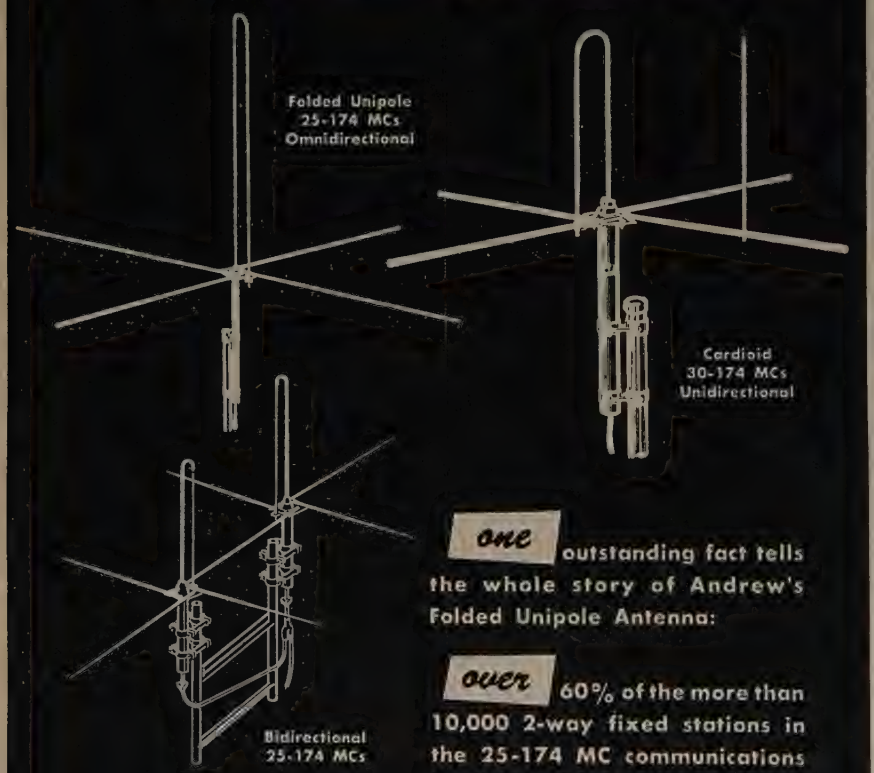
all others combined!



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(Continued from page 92A)

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Spiegel, S. S., R.D. 16, Box 45, Baltimore 21, Md.
Stack-Forsyth, E. F., Natal Technical College, Durban, Natal, South Africa
Webster, S. K., 1511 E. Hyde Park Blvd., Chicago 15, Ill.
Wetz, R. H., 304 W. McMillan St., Cincinnati 19, Ohio

The following elections to Associate grade were approved and are effective as of November 1, 1951:

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Aldridge, C. A., 201 Waverly Ave., Syracuse, N. Y.
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Allen, S. I., 507 Falley St., Richland, Wash.
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Allison, N. B., 157 Iroquois Ct., Lexington, Ky.
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Baroch, G. F., 109 S. Lodge Lane, Lombard, Ill.
Barthel, E. A., 127 W. Evergreen, San Antonio, Tex.
Barton, R., 3210 Chillum Rd., Apt. 301, Mt. Rainier, Md.
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Boguslawski, H. A., 310 W. 21 St., New York, N. Y.
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Cox, T. J., 35-B Ben Tillman, Naval Base, S. C.
Cronk, E. M., 9E Sgt. Jasper Apartments, Charleston, S. C.
Curtis, F. H., 729—55 St., Downers Grove, Ill.
Danielson, F. H., Box 632, AA & GM Br., TAS, c/o Philco Corp., Fort Bliss, Tex.
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Evans, S., Jr., 2817 Statford Ave., Clifton, Ohio
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(Continued on page 96A)

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GROUP	LENGTH	ENVELOPE	DEFLECTION ANGLE	ION TRAP	CAPACITANCE (uuf)	TYPE FACE PLATE
16AP4	21¼	M	52	D	M	Clear
16AP4A	21¼	M	52	D	M	Grey
16CP4	21½	G	52	D	2000	Clear
16CP4A	21½	G	52	D	2000	Grey
16LP4	22⅝	G	52	S	2000	Clear
16LP4A	22⅝	G	52	D	2000	Grey
16ZP4	22⅝	G	52	D	2000	Clear
				D	2000	Grey

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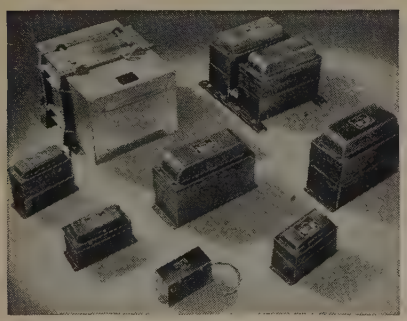

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(Continued on page 98A)

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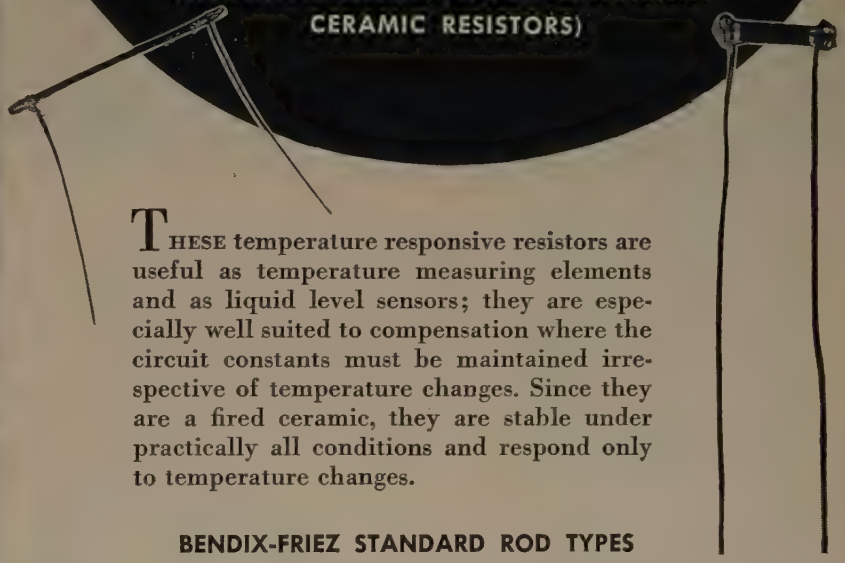
(NEGATIVE TEMPERATURE CO-EFFICIENT CERAMIC RESISTORS)



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Size (inches)	@ +30°C.	@0°C.	@ −30°C.
.140 x ¾	45 ohms	88 ohms	193 ohms
.040 x 1.5	14,000 ohms	29,946 ohms	74,676 ohms
.018 x 1.5	40,000 ohms	94,040 ohms	262,400 ohms

Typical application in capsule form for temperature sensing of hydraulic oil.

Many other values can be obtained from standard diameter material. Because the thermistors are made in our own plant, under extremely careful control, special compositions, shapes, and resistance values, hermetically sealed or otherwise protected, can be made in any quantities to suit your individual requirements.

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Positions Wanted

(Continued from page 102A)

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B.S. and M.S. in Physics. Age 28. 3 years' experience in teaching, 1 year in research. Desires research position in Queens or Long Island, N.Y. Write Box 543 W.

(Continued on page 105A)

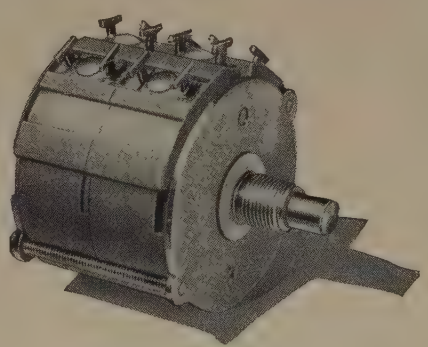
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 62A)

Multiple Control

Simultaneous control of from 2 to 20 circuits or functions is possible with the Series 42A potentiometer. The multiple control unit is now offered in tandem assemblies made to order by **Clarostat Mfg. Co., Inc.**, Dover, N. H.



Series 42A potentiometer is encased in a mineral-filled bakelite housing designed to lock together with similar units to form a single tandem assembly. The contact arm of each unit can be adjusted on the common shaft. Mechanical rotation may be continuous or limited. Electrical rotation is 345 degrees and can be adjusted to within ±1 degree. This can be increased to 359 degrees for special requirements.

Resistance range of each Series 42A potentiometer is 100 to 100,000 ohms for linear windings. Tapered windings are also available. Linear controls are rated at 3 watts, while tapered controls depend on the nature of their taper. Standard overall resistance tolerance is ±5 per cent. Ratio of voltage at any point on the potentiometer to total impressed voltage can be within 0.5 per cent of the theoretically correct value.

(Continued on page 104A)

TO AIRCRAFT ELECTRICAL and RADIO DESIGNERS

LOCKHEED

has a great future

—make it yours!

There's a great future waiting for you in Southern California—helping create the planes of the future in Lockheed's long-range development program. Lockheed is building planes for defense, planes for the world's airlines. You are needed to help carry on this program—a program that offers you not just a job, but a future!

Lockheed also offers you: Increased salary rates, generous travel allowances, a chance to live in Southern California, and many other benefits only a company like Lockheed can provide.

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Design experience in aircraft electrical installation, circuit layout and systems analysis; experience in radio and radar circuit design and installations, as applied to aircraft.

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Housing conditions are excellent in the Los Angeles area. More than 35,000 rental units are available. Thousands of homes have been built since the war; huge tracts are under construction now. You will find the school system as good—from kindergarten to college.

Send today for free, illustrated brochure describing life and work at Lockheed in Southern California. Use handy coupon below.

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ELECTRONIC ENGINEERS

THE WALL STREET JOURNAL
Friday, September 28, 1951

Westinghouse Air Brake Acquires Melpar Stock

Westinghouse Air Brake Co. has acquired all the stock of **Melpar, Inc.**, of ALEXANDRIA, VA., and CAMBRIDGE, MASS.

Melpar has prime contracts with the armed services covering the fields of sonar, radar, communications, guided missiles, computers and miniaturization. The new owners plan a "large expansion program" geared to meet increasing demands by the armed services, according to Edward O. Boshell, chairman and president of Westinghouse. He described the purchase as "an important step in our expansion program."

The Westinghouse expansion program is directed toward permanent peace time growth in industrial electronics.

OPPORTUNITIES FOR YOU

exist in the expansion program outlined above if you have experience in one or more of the following fields:

COMPUTERS
TELEMETERING
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Send resume to
Personnel Director

MELPAR, INC.
452 Swann Ave., Alexandria, Virginia

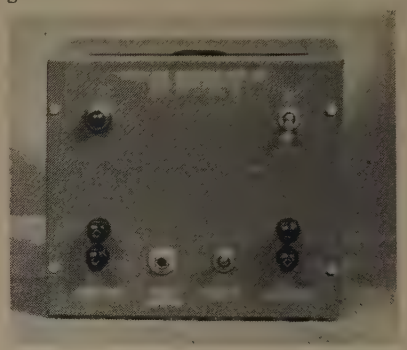
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 103A)

Single Sweep CRO Accessory

The Sterling Instruments Co., Engineering Dept., 13331 Linwood Ave., Detroit 6, Michigan, announces Type 121 Single Sweep Accessory. This instrument is designed to provide only one pulse to trigger the single sweep of a Cathode-Ray Oscillograph at the start of any complex wave pattern, and at no time thereafter. Type 121 provides a single negative output pulse for triggering the single sweep from either a positive or negative input signal without the necessity of separate adjustments for positive and for negative signals.



The signal input required is approximately 0.1 volt and may be obtained from the signal itself or from an external transducer.

The Type 121 may be reset by means of the panel switch or by remote control. The unit is entirely self contained and operates from 110 volt 50 to 60 cps input.

Portable Radiation Probe

A new lightweight radiation probe, for detecting and measuring alpha, beta, gamma, and neutron radiations, has been announced by **General Electric Co., Special Products Div.,** Schenectady 5, N. Y.

The scintillation counter, which has all the usual advantages of such an instrument, includes a phosphor, photomultiplier tube, and a two-stage amplifier with low-impedence output. Light flashes, produced when nuclear particles strike the phosphor, are converted into electrical pulses by the photomultiplier. This allows radiation detection and measurement under even the most difficult circumstances. Alpha particles, for example, can be counted even in the presence of high beta-gamma backgrounds.

The phosphors for detecting alpha, beta, gamma, and neutron radiations are incorporated into specially designed caps placed on the end of the probe. These detecting heads can be quickly interchanged and the various phosphors in the caps are easily replaced should the need arise.

The neutron cap alone, adapted to measure beams of thermal neutrons, is expected to have wide application in general health physics work.

The complete detector is $2\frac{3}{8}$ inches in diameter, 15 inches long, and weighs approximately 10 pounds

(Continued on page 105A)

Positions Wanted

(Continued from page 104A)

MICROWAVE-PULSE ENGINEER

Desires executive-administrative position. 9 years' experience in radar, microwave communication. Author of many articles, text. Box 538 W.

ENGINEER

Age 44, married. Extensive practical radio, EM, TV and communications experience. Presently employed as Instructor of radio, FM, TV and communications; 4 years' Signal Corps radio officer. 1st class radio telephone license. Desires position in TV or communications field, New York, New Jersey or Connecticut area. Resume on request. Minimum starting salary $5600 per year. Box 539 W.

ELECTRONIC ENGINEER

B.E.E. June 1950, Syracuse University. Age 25, married, 1 child. Instructing circuit and design analysis of AM, FM and television receivers. Formerly research assistant on antenna research project, and radio and radar technician. Desires engineering position with peacetime application. Box 540 W.

ELECTRONIC ENGINEER

B.E.E. June 1949. Communications option. Rensselaer Polytechnic Institute. 3 years' Electronic Technician 1/c U.S. Navy. 2½ years experience in development, test, and test supervision in the field of analog computers. 2 years' M.B.A. New York University major management. Desires position requiring technical competence and offering executive training. Résumé on request. Write Box 544 W.

(Continued on page 106A)

ELECTRONICS ENGINEER—SENIOR

Sound theoretical background and 5 to 10 years experience desirable. Will be required to design and construct Special Instruments and Apparatus needed for research in resistors, capacitors, & fundamental properties of conductors. Permanent position electric components manufacturer located in Eastern U.S.

ADDRESS D-19,
P.O. BOX 3414
PHILA. 22, PA.

LOOKING AHEAD?

If you're a top performer in the field of physics, electronic engineering or design, and you're looking for a *career* as well as a well-paid position, it will pay you to investigate the excellent opportunity we offer.

BASIC QUALIFICATIONS:

Minimum of four year's experience in advanced research or development related to:

- **PULSE CIRCUITS**
- **COMPUTERS**
- **NUCLEAR INSTRUMENTS**
- **MINIATURIZATION**

* * *

ILLUSTRATED BROCHURE on request. Please write (giving summary of your education and experience, plus salary requirements) to:

THE BERKELEY SCIENTIFIC CORP.
2200 Wright Avenue
RICHMOND, CALIFORNIA

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 104A)

Toroidal Cores

Moulded powdered-iron toroids are now being produced by **Lenkurt Electric Co.**, 1129 County Rd., San Carlos, Calif. The size range extends from 0.800 to 3.375 inches outside diameters. Included is the

wedding-ring, the smaller size illustrated. These are available in magnetic materials which can be chosen to accentuate high-Q, high inductance, low generation of harmonic distortion products, high magnetic and temperature stability, or small size and low cost. The same cores are also supplied wound to individual specifications, cased, uncased, or hermetically sealed.

(Continued on page 106A)

- **ELECTRONIC DESIGN ENGINEERS**
- **TECHNICAL WRITERS**
- **DESIGN DRAFTSMEN**
- **PHYSICISTS**

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- Power Line Carrier Communication Equipment
- Railroad Radio
- Radio Frequency Heating
- Medical and Industrial X-ray
- Commercial Radar
- Balancing Equipment
- Military Radar (ship, ground, airborne)
- Military Transmitters
- Specialized Electronic Equipment
- Fire Control Systems
- Automatic Pilots
- Guided Missiles

Check These Outstanding Benefits: Top pay, ideal working conditions, advancement on merit, graduate study opportunities, employee scholarships, paid re-location expenses, Baltimore location.

Send resume of experience and education to: Manager of Industrial Relations, Westinghouse Electric Corp., 2519 Wilkens Ave., Baltimore 3, Md.

YOU CAN BE SURE...IF IT'S

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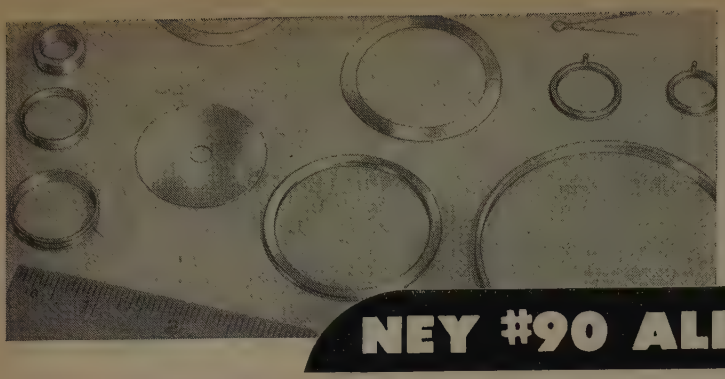


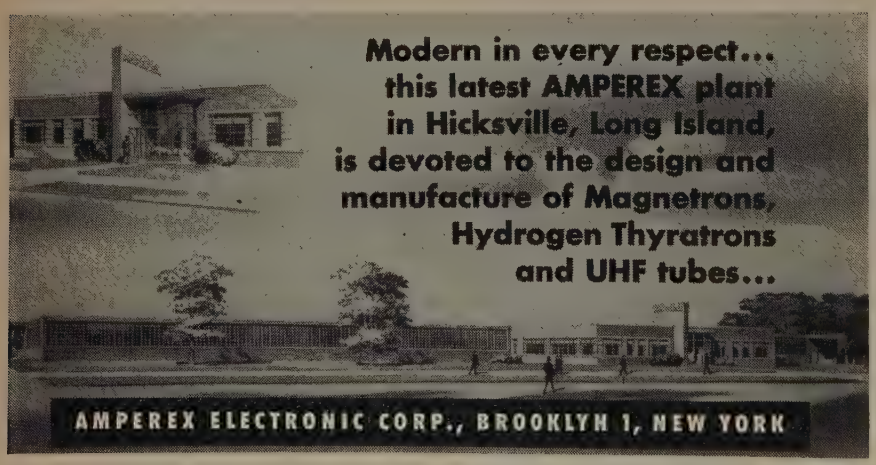
"JUST RIGHT" HARDNESS . . . SURFACE FINISHED FOR SLIP RINGS AND COMMUTATOR BARS

NEY #90 Alloy, overcomes many of the disadvantages of coin silver when used in slip ring and commutator bar applications. Actually a modification of coin silver, NEY #90 is subjected to a carefully controlled processing that produces a uniform hardness of 120-130 Brinell which has been found best for slip ring type applications. Since performance is also markedly influenced by surface condition, especially when brush pressure must be low, NEY #90 Alloy rings are given a specially developed finish that greatly reduces wear and electrical noise. NEY #90 Alloy is available in seamless tubing in all sizes up to 4" O. D., also in the form of plate, rod, wire and fabricated parts.

Write for your copy of new Ney Data Book, "NEY PRECIOUS METALS FOR NON-CORROSIVE WEAR-RESISTANT PARTS." (Bulletin R-12)

THE J. M. NEY COMPANY, 171 Elm Street, Hartford 1, Connecticut
SPECIALISTS IN PRECIOUS METAL METALLURGY SINCE 1812.

19NY51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AMPEREX ELECTRONIC CORP., BROOKLYN 1, NEW YORK

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ELECTRICAL and ASSISTANT ELECTRICAL ENGINEERS

needed for circuit design, and development of new components for digital computers. Engineers with 1 to 4 years experience in pulse circuits and techniques.

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- Interviews arranged at our expense

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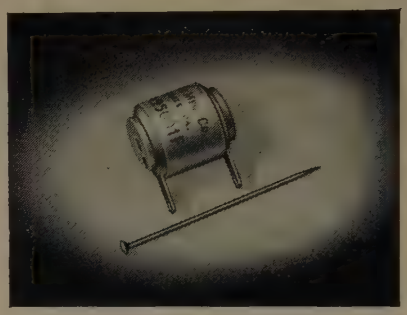
(Continued from page 105A)

Precision Resistors in Lug Types

Miniature hermetically-sealed resistors with solder lug terminals and designed to meet the requirements of JAN-R-93, characteristic A, style RB11, have been announced by the **Shallcross Manufacturing Co.**, Collingdale, Pa.



Known as Akra-ohm type 1180, the resistors are 19/32 inch long $\times \frac{1}{2}$ inch diameter and are rated 0.25 watt at 250 volts. Resistance values up to 0.1, 0.3 or 0.4 megohms may be obtained depending on the alloy wire used for the non-inductive winding. The resistors are hermetically-sealed in Steatite by a patented Shallcross process which provides immunity against the effects of humidity, fungus and salt water immersion.

This and other hermetically sealed resistor types in accordance with JAN styles RB12A and RB14A, as well as twelve other JAN characteristic B styles, are described in the new Shallcross resistor bulletin R-3b.

Reactivator for C-R Picture Tubes

Transvision, Inc., Dept. DG, New Rochelle, N. Y., announces a new C-R tube reactivator.

Weighing 3 pounds, this portable instrument plugs into any 110 v receptacle. It is self-powered and completely self-contained.

The reactivation can be done if necessary, without removing the tube from the set. In the majority of cases the reactivation is complete and permanent. Light

(Continued on page 107A)

News—New Products

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(Continued from page 106A)

emission increases, brightness goes up, and detail is enlivened. It must be noted, however, that the reactivator will not work on broken filament, broken glass, or shorted components.

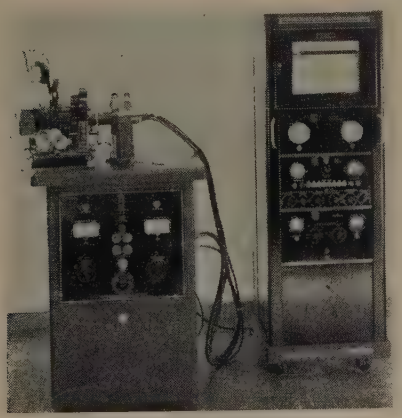
In brief, degeneration follows this pattern: Gases are released by tube elements and casing walls after prolonged heated operation. These gases combine with the pure barium on the surface of the cathode, poisoning the cathode so that electrons are no longer emitted from the surface.

Normally, this surface is replaced by a new coating of barium being formed.

Unlike devices used for "flashing" the filament, or permanently raising the filament temperature for temporary relief, this reactivator gives a full reactivation complete with a short aging cycle.

Fluorescence Analysis Unit

The new Fluorescence Analysis Unit, which incorporates many design improvements to facilitate rapid qualitative and quantitative analysis of constituents in metals, alloys, minerals, ores, chemical mixtures and compounds, is now in production at the **Research & Control Instruments Div., North American Philips Co., Inc.**, 750 S. Fulton Ave., Mount Vernon, N. Y.



The unit employs a wide range vertical goniometer with a sweep radius of 170 mm instead of the horizontal assembly used on the original model. The new equipment utilizes a horizontal, water-cooled oil-insulated X-ray tube operated from a standard water-cooled Norelco diffraction unit.

The output of the special volume-sensitive Geiger counter is processed in electronic circuits for the purpose of driving a strip chart recorder or a count register. The chart instrument is used for normal qualitative and quantitative analysis and the register is employed where extreme quantitative precision is required.

As distinguished from X-ray diffraction which gives precise data about atomic structure, Fluorescence Analysis provides precise quantitative and qualitative data with respect to the elements present. Diffi-

(Continued on page 108A)

CONTINUOUSLY
VARIABLE FILTERS
MODEL 302
VARIABLE ELECTRONIC FILTER

"Another SKL first"

The — SKL — Model 302 includes two independent filter sections, each having a continuously variable cut-off range of 20 cps to 200 KC. Providing a choice of filter types each section has 18 db per octave attenuation. When cascaded 36 db is obtained in the high and low pass setting and 18 db in the band pass position. With low noise level and 0 insertion loss this versatile filter can be used as an analyzer in industry and the research laboratory or to control sound in the communications laboratory, radio broadcasting, recording and moving picture industries.

SPECIFICATIONS

- CUT-OFF RANGE 20 cps to 200 KC
- SECTIONS 2—can be high, low and band pass
- ATTENUATIONS 36 db/octave maximum
- INSERTION LOSS . 0 db
- NOISE LEVEL 70 db below 1 volt
- FREQUENCY RESPONSE 2 cps to 2 MC

SKL SPENCER-KENNEDY LABORATORIES, INC.
181 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS.

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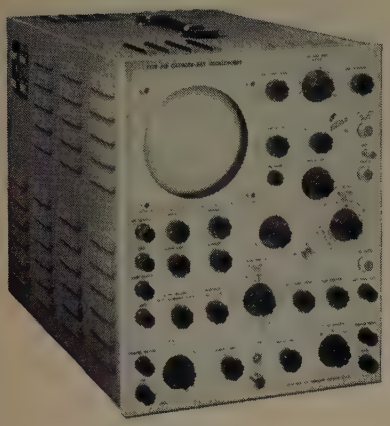
GREETINGS
1951
AGASTAT TAKES TIME OUT TO RELAY THE SEASON'S GREETINGS
AMERICAN GAS ACCUMULATOR COMPANY • 1027 Newark Ave., Elizabeth 3, N. J.

VERSATILITY by TEKTRONIX



TEKTRONIX TYPE 512
CATHODE RAY OSCILLOSCOPE

Sensitivity and Frequency Range:
.15v/cm — dc-2mc
.005v/cm — dc-1mc

Sweep Range:
.3sec/cm — 3usec/cm, standard
(1sec/cm or 3sec/cm available on special order)

Accuracy of Measurement:
2% of full scale reading, both sweep timing and amplitude. 9 inches of logarithmic scale per decade of range.

Triggered or Repetitive Sweeps

Differential Vertical Amplifier

D.C. Voltages Regulated for A.C. Line Fluctuations Between 105-125v.

The Tektronix Type 512 Cathode Ray Oscilloscope has proven to be a most versatile research and development tool, capable of providing accurate information to workers in many different fields. A partial list of the uses to which it has been put includes the following:

AUDIO RESEARCH AND DEVELOPMENT
BIOPHYSICAL AND MEDICAL RESEARCH
COMPUTER DEVELOPMENT
MONITORING OF PARTICLE ACCELERATORS
GEOPHYSICAL RESEARCH
INVESTIGATION OF SUBSONIC AND SUPERSONIC PHENOMENA
QUALITATIVE CHEMICAL ANALYSIS BY POLAROGRAPH METHODS

If your instrumentation needs require an oscilloscope of exceptional accuracy and operating stability, we invite you to investigate the Type 512. We will be pleased to send you information on any or all of our products.

TEKTRONIX, Inc.
P. O. Box 831, Portland 7, Oregon • Cables: Tektronix

News—New Products

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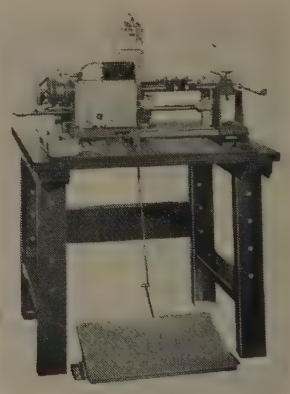
(Continued from page 107A)

cult analyses involving solids, semi-solids and liquids can be carried out in much less time than when ordinary chemical methods are employed. Moreover, Fluorescence Analysis is entirely nondestructive and permits analysis of very small specimens.

The new unit operates at potentials up to 50 ma. The basic diffraction assembly measures 28 inches deep, 30 inches wide and 70 inches high. The associated electronic circuit cabinet is 23 inches deep, 20 inches wide and 71 inches high.

Heavy Wire Bobbin and Transformer Winder

Manufactured by **George Stevens Mfg. Co., Inc.**, Pulaski Rd. at Peterson, Chicago 30, Ill. A new Model 117-A winds heavy wire bobbin and transformer coils for regular production, laboratory or experimental use in military and other types of equipment where space is critical. Wire sizes as large as 14 gauge are wound in tight, uniform layers, without tangling or miswinding at the ends of layers during reversing. High tension is applied through high winding power and a heavy winding head to put wire exactly where desired. No loss of turns and accurate margins are assured by a screw feed and an electrically controlled clutch.



Model 117-A is suited for winding heavy wire bobbin and transformer coils up to 6 inches long, and up to 9 inches outside diameter if round. Rectangular coils' clearance is 4½ inches. Model 117-A can also be used for single layer close or space windings. At slight additional cost and on special order a winding traverse up to 8 inches or more can be supplied. Mandrels up to 14 inches long may be used.

One Model 92-6D tension is furnished for wire gauges 18 to 24, and spools up to 6 inches diameter. Other tension available is Model T-8 for wire gauges 16 to 24. Model 92-2 for wire gauges 14 to 24, or Model 92 for wire gauges 24 to 44. Winding speeds up to 2,000 rpm are possible with 32 pitch gears providing winding range from 10 to 500 turns per inch. Length of winding is determined by micro-precision reversing mechanism. Gears range in size from 30 to 100 teeth.

(Continued on page 110A)

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A New Development

For:

- **RF Shielding**
- **Radar Reflection**
- **Massive Surface Conductivity**

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THE NEW RADA-PULSER for laboratory, production line and field.

MEASURES TRANSIENT RESPONSE OF MILITARY AND COMMERCIAL RECEIVERS AND SYSTEMS.

SPECIFICATIONS

CARRIER FREQUENCIES: 30 mc and 60 mc.
PULSE WIDTHS: 0.1 and 0.25 microseconds.
PULSE REPETITION RATE: Continuously variable from 500 to 2000 pps.
MAXIMUM RF OUTPUT: Approximately 1 volt at 70 ohms.
ATTENUATORS: 20 db, 20 db, 10 db, switched 10 db, continuously variable.
PULSE OUTPUT: 50 volts at 70 ohms. (Jack provided to permit use of envelope pulses).
EXTERNAL MODULATION: Input terminals provided to permit modulation by other pulse widths from external source.
TRIGGER PULSES: Positive and negative furnished ahead of pulsed carrier to trigger oscilloscope sweep circuit.
REGULATED POWER SUPPLY.

PRICE: $595.00, F.O.B. FACTORY

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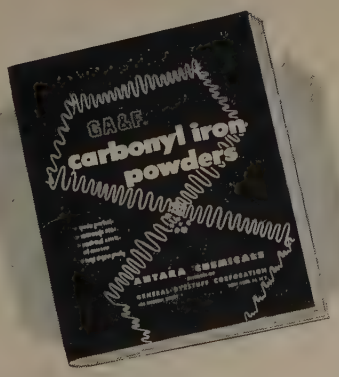
Export Department: 13 East 40th Street, New York 16, N.Y.

KAY

KAY ELECTRIC COMPANY

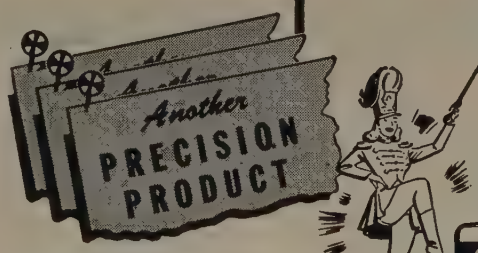
14 Maple Avenue — Phone CAldwell 6-4000 — Pine Brook, New Jersey

YOURS for the asking . . .



. . . The most comprehensive treatment ever given to the characteristics and applications of Carbonyl Iron Powders. 32 pages—fully illustrated and documented. Your copy will be sent upon your request to Department 98, Antara Chemicals, Division of General Dyestuff Corp., 435 Hudson Street, New York 14.

GA&F® Carbonyl Iron Powders



FOLLOW THE PARADE TO THE *New* Burlington *Hermetically Sealed* INSTRUMENT

JUST PLAIN RUGGED

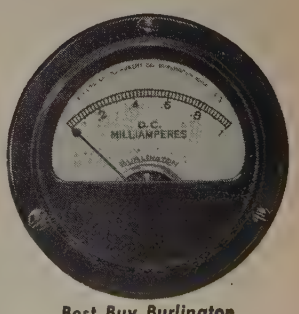
. . . yet an instrument of highest QUALITY

. . . PRECISION

. . . ACCURACY

The Burlington "Hermetically Sealed" *Instrument* was designed and is manufactured to conform to JAN specifications for sealed *instruments*.

- Steel case with heavy copper-cadmium plate and black finish.
- Excellent shielding due to case material and construction.
- Double strength clear glass.
- Black satin onodized aluminum bezel.
- Glass to metal seal under controlled humidity and temperature conditions.
- D'Arsonval permanent magnet type movement for DC applications.
- Designed to enhance panel appearance.
- Available in 1½" square, 2½" and 3½" round case types.
- Guaranteed for one year against workmanship and materials.



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DEPT. I-121, BURLINGTON, IOWA

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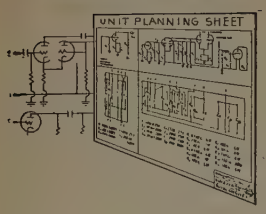
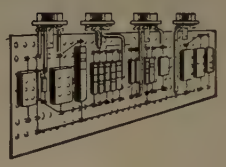


ALDEN TERMINAL CARD MOUNTING SYSTEM

ORGANIZE CIRCUITS QUICKLY FOR SYSTEMATIC LAYOUT AND CONSTRUCTION

Use Alden Unit Planning Sheet (at left) to lay out circuit blocks of logically associated functions for mounting on pre-punched multi-hole Alden Terminal Cards (right).

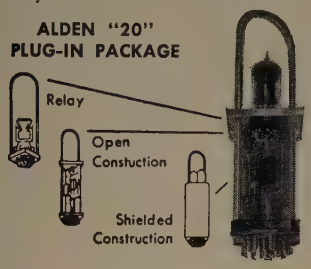


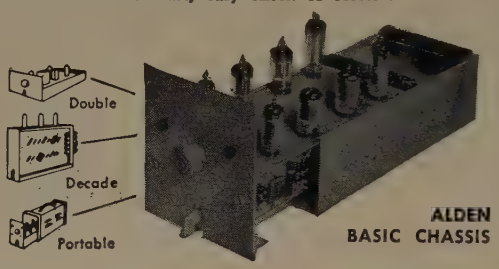
GET THE MOST NATURAL EASY SUB-DIVISION OF LABOR

with Alden Miniature Terminals and sockets mounted to terminal card as per Unit Planning Sheet layout. Components are mounted and are wired completely as an open, accessible sub-assembly.

INSURE LOWEST OPERATING AND SERVICE COSTS

Completely wired circuitry on Alden Terminal Card is easily assembled into plug in units—Alden "20" Plug In Packages and Basic Chassis—Making circuitry instantly accessible-removable for fast, easy check or service.





TO START QUICKLY! Call Brockton 160 or wire for a laboratory sample Basic Chassis at $40.00 or Open and Closed Plug In Packages at $10.00—or write for booklet: "Basic Chassis and Components for Plug In Unit Construction.

NA-ALO **ALDEN PRODUCTS COMPANY**

121 N. Main St., Brockton 64, Mass.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 108A)

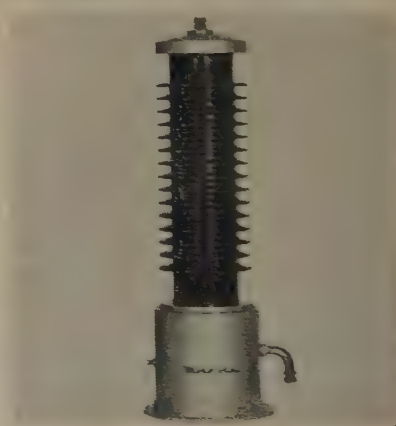
Continuously Variable Filtered DC Power

A moderately priced dc power supply, Model N, with an output range of 0–28 volts at 15 amperes is announced by **Electro Products Laboratories, Inc.,** 4501 N. Ravenswood Ave., Chicago 40, Ill. A feature is the application of selenium rectifiers which increases the rectifier power rating and permits lower cost per ampere output. A single control furnishes continuous voltage adjustments for different load conditions over the specified range.

It supplies up to 36 volts at 6 amperes. The ac power is approximately 730 watts with a 15 ampere 28 dc volt load. The ac hum or ripple at 15 amperes is 8 per cent, at 10 amperes, 5 per cent. Facilities for additional filtering are provided for special requirements. The D'Arsonval-type voltmeter and ammeter are accurate to 2 per cent. A Superior Powerstat provides incremental voltage adjustments. Bridge-type heavy duty selenium rectifiers permit continuous duty at 15 amperes. It operates from a 110–120 volt, 50/60 cps ac power source.

Aperiodic Coupling Unit

Motorola Inc., 4545 W. Augusta Blvd., Chicago 51, Ill., has announced the introduction of the Aperiodic Line-Coupling Unit which makes use of an integral high-pass filter in a new approach to the problem of coupling carrier equipment to power lines.



This unit, with a flat pass characteristic above 50 kc, permits broadband

(Continued on page 111A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 110A)

coupling. Any number of receivers may be coupled through one Aperiodic unit, as can any number of transmitters with up to 25 watts total output power. In addition, multiple-frequency by-pass at switching points is readily accomplished, by utilizing only two Aperiodic units.

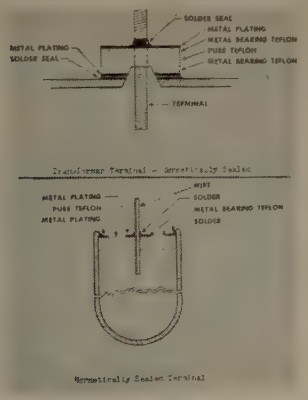
Basically, a coupling unit is intended to transfer the high-frequency carrier (50–200 kc) onto the power line with a minimum of attenuation. In most former installations, a series resonant circuit was utilized, of which the high voltage coupling capacitor was an element.

In all cases one Aperiodic Unit will replace the older coupling capacitor with its multiple line tuning equipment.

Aperiodic units are available in voltage classes of from 34.5 kilovolts to 230 kilovolts. With each unit a grounding switch, a drain coil, protective gaps, fuse, line-tuning unit, and impedance-matching transformer are included. The unit meets all requirements of AIEE Spec. 31 and has been tested by an independent laboratory to conform to these specifications.

Teflon Hermetically Sealed to Metals

The United States Gasket Co., Teflon Products Div., P. O. Box 93, Camden 1, N. J., has recently succeeded in sealing fluorocarbon resins to any one of several metals, resulting in an hermetic seal which is best described as a fused seal capable of holding a vacuum for sustained periods.



The company is able to design various types of terminals, printed circuits or metal faced Teflon sheets, rods or cylinders for particular problems. Preliminary evaluation shows that the structure is microcrystalline in nature and the seal gradually changes from a pure fluorocarbon resin to a pure metal.

Because of the physical characteristics of Polytetrafluoroethylene (Teflon), seals can be made to withstand vibration, shock, high and low ambient temperature limits and thermal shock. These "Chemelec" seals can be designed for a broad range of electrical conditions ranging from insulator, to semi-conductor, to low resistance conductor, and rf shield, or any combination of these in the same unit.

(Continued on page 112A)

RECTIFIER TUBES

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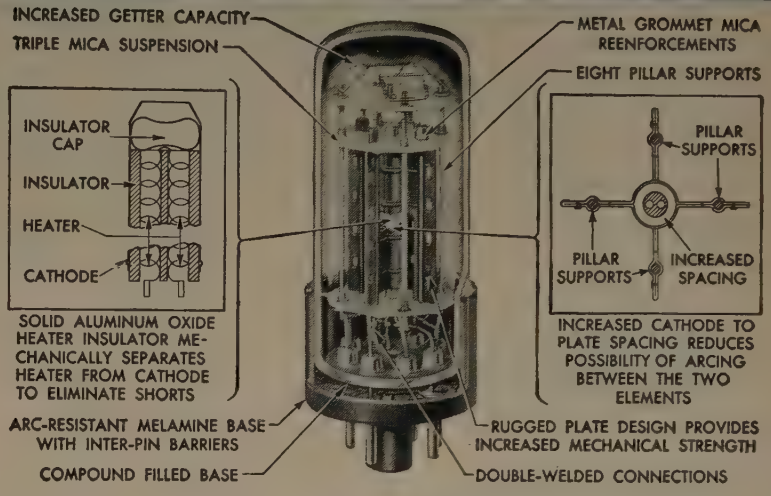
FOR ADDED RELIABILITY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TRIPLE MICA SUSPENSION
INSULATOR CAP
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CATHODE
SOLID ALUMINUM OXIDE HEATER INSULATOR MECHANICALLY SEPARATES HEATER FROM CATHODE TO ELIMINATE SHORTS
ARC-RESISTANT MELAMINE BASE WITH INTER-PIN BARRIERS
COMPOUND FILLED BASE
METAL GROMMET MICA REENFORCEMENTS
EIGHT PILLAR SUPPORTS
PILLAR SUPPORTS
PILLAR SUPPORTS
INCREASED SPACING
INCREASED CATHODE TO PLATE SPACING REDUCES POSSIBILITY OF ARCING BETWEEN THE TWO ELEMENTS
RUGGED PLATE DESIGN PROVIDES INCREASED MECHANICAL STRENGTH
DOUBLE-WELDED CONNECTIONS

We are not in the standard vacuum tube business, but we are in the business of developing and manufacturing a reliable line of special purpose electron tubes—tubes that will serve and meet the stiff and varied operational requirements of aviation, ordnance, marine and other fields of modern industry. Typical of these are receiving type tubes such as Beam-Power Amplifiers, R-F Pentodes, Twin Triodes, and the Full-Wave Rectifiers illustrated above and described below. All of these tubes are exhausted on a special automatic exhausting machine capable of extra high evacuation, and are aged under full operating and vibration conditions for a period of 50 hours. In addition to the tubes described above, Eclipse-Pioneer also manufactures special purpose tubes in the following categories: gas-filled control tubes, Klystron tubes, spark gaps, temperature tubes and voltage regulator tubes.

LOOK FOR THE PIONEER MARK OF QUALITY
REG. U. S. PAT. OFF.

Electrical Characteristics of E-P Full-Wave Rectifier Tubes

TUBE TYPE	R.M.A. 5838	R.M.A. 5839	R.M.A. 5852	R.M.A. 5993
Heater Voltage	12 volts	26.5 volts	6.3 volts	6.3 volts
Heater Current	0.6 amps.	0.285 amps.	1.2 amps.	0.80 amps.
Peak Inverse Voltage	1375 v. (max.)	1375 v. (max.)	1375 v. (max.)	1250 v. (max.)
Peak Plate Current (per plate)	270 ma. (max.)	270 ma. (max.)	270 ma. (max.)	230 ma. (max.)
D-C Heater-Cathode Potential	450 v. (max.)	450 v. (max.)	450 v. (max.)	400 v. (max.)
Cathode Heating Time	1 min.	1 min.	1 min.	45 sec.
Total Effective Plate Supply Impedance	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)

Other E-P precision components for servo mechanism and computing equipment:

Synchros • Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies and remote indicating-transmitting systems.

For detailed information, write to Dept. G

ECLIPSE-PIONEER DIVISION of Bendix AVIATION CORPORATION

TETERBORO, NEW JERSEY

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

SECON development and production METALLURGISTS

BASE, RARE AND PRECIOUS METALS AND ALLOYS
SMALL UNITS
SMALL SIZES
CLOSE TOLERANCES

Nickel alloy, filament wire and ribbon: flat, grooved, crowned.

Grid wire electroplated.

Alloys for special requirements, bare or enameled.

•

Further details upon request.

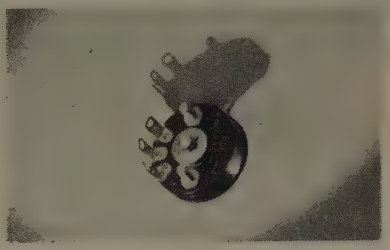
SECON
METALS CORPORATION
228 East 45th Street, New York 17, N. Y.
MUrray Hill 7-1594

News—New Products

(Continued from page 111A)

Miniature Resistor

Centralab Div., Globe-Union Inc., 900 E. Keefe Ave., Milwaukee 1, Wis., announces production of its new high-torque Model I Radiohm Control, designed specifically for maintenance of circuit balance under conditions of vibration. This unit is intended for equipment used in commercial or government installations where miniature size also is a requisite.



The Model I has a torque-range from 2 to 4 ounce-inches. It is available in plain type with screwdriver slot on either end, or with conventional knob adjustment. Screwdriver adjustment makes the high-torque Model I Radiohm most desirable where repeated adjustments are not practical.

This unit also can be supplied with a dust cover or electrostatic shield. It is identical in size and resistance ranges to regular Model I Radiohm controls.

For further details write for bulletin #42–158.

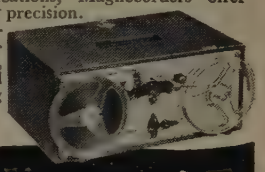
(Continued on page 114A)

MAGNECORD *Sound Research**

*FINDS A FIELD OF BLACK GOLD

Modern engineers know that black gold is where you find it . . . scientifically! That's why they use Magnecord tape recorders in their search for new oil supplies. Magnecord recordings of signals from sensitive electronic instruments help determine the depth and location of oil bearing rock strata.. Whatever your recording problem in science, industry or communications, Magnecorders offer greater fidelity and precision.

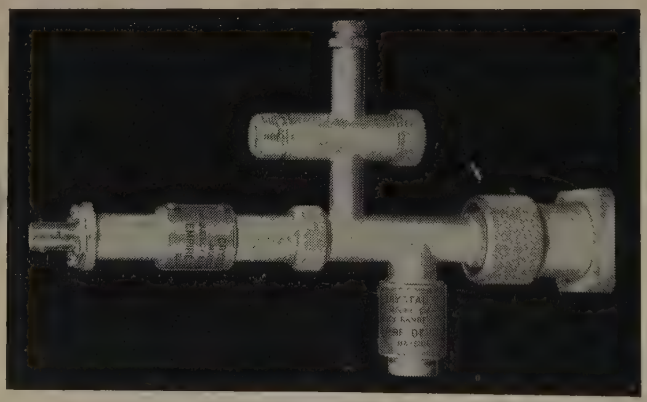
Available for subsonic, audio and supersonic research, Magnecord can fill your most exacting requirements.



Magnecord, INC.

HIGH FIDELITY TAPE RECORDERS FOR INDUSTRY
Write for New Catalog Dept. P-12
Magnecord, Inc., 360 N. Michigan Ave., Chicago 1, Ill.

COAXIAL CRYSTAL MIXER
BROAD BAND
FIXED TUNED



Broad Band Crystal Mixer Model CM107

INPUT VSWR: Better than 2 to 1, without adjustments, for all frequencies within the nominal frequency range.

LOCAL OSCILLATOR POWER REQUIREMENT: 10 Milliwatts. Oscillator injector is adjustable to accommodate large variations in oscillator power.

LOCAL OSCILLATOR VSWR: Better than 2 to 1 with any L. O. injector adjustment.

LOCAL OSCILLATOR REJECTION AT I. F. OUTPUT: Better than 30 DB.

MODEL	FREQ. RANGE IN MC
CM-107A	225 to 400
CM-107A1	300 to 530
CM-107A2	510 to 760
CM-107B	750 to 1210
CM-107C	1120 to 1700
CM-107D	1700 to 2600

Other frequency ranges up to 5600 MC available.

EMPIRE DEVICES' expert engineering staff is available to give careful attention to your problems. Your inquiries are invited.

EMPIRE DEVICES, INC. 38-25 BELL BOULEVARD, BAYSIDE 61, N. Y.

MANUFACTURERS OF FIELD INTENSITY METERS • DISTORTION ANALYZERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS

The Largest Selling LIGHTNING ARRESTER *At Any Price!*

NO. AT102

APPROVED

JUMBO

Protects Home and TV Set Against Lightning Hazards

$2.25 LIST

U.S. Patent No. D-4664

- Installs anywhere
- No wire stripping, cutting or splicing

(Complete with strap and ground wire.)

OVER 1,000,000 IN USE TODAY!

See Your Jobber or Write for Form No. 84

JFD MANUFACTURING CO., Inc.
6137 M 16th AVENUE, BROOKLYN 4, N. Y.
FIRST in Television Antennas and Accessories

DYNAMIC ANALYSIS

Opportunities for man qualified to head group engaged in Guided Missiles guidance systems, analysis and design, Servo-Mechanism Theory, Aero Elasticity and Simulator work. A prominent and responsible position for a man with applicable technical, supervisory and leadership qualifications.

•

Write in confidence to

MR. RALPH BICKFORD

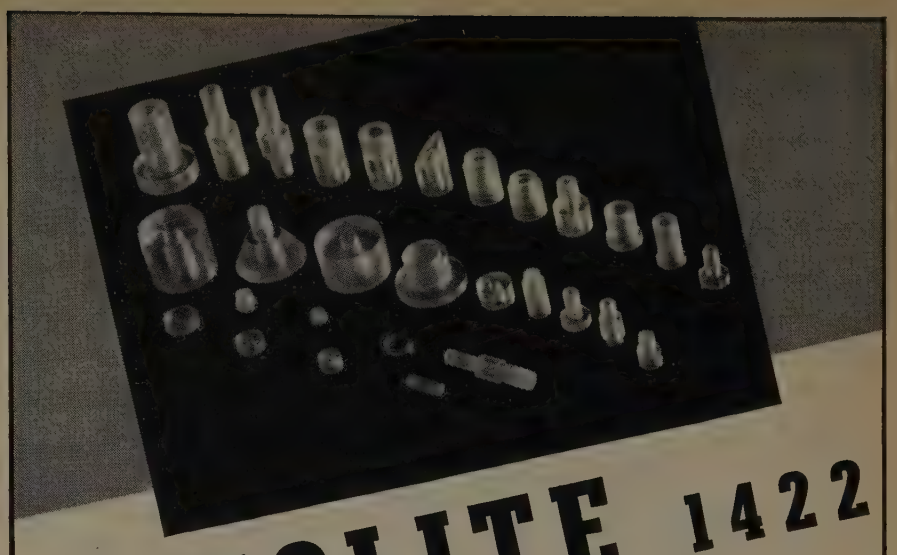
Industrial Relations Manager

ENGINE AND AIRPLANE CORPORATION

FAIRCHILD

Guided Missiles Division

FARMINGDALE, L. I., N. Y.



REXOLITE 1422

(FORMERLY G. E. TEXTOLITE 1422)

COMBINES EVERY DESIRABLE PHYSICAL, CHEMICAL, & ELECTRICAL PROPERTY IN ONE INSULATION MATERIAL FOR U. H. F.

REXOLITE 1422

- Meets JAN-P-77 and MIL-P-77A specifications.
- Specifically designed to meet the growing need for a U. H. F. insulating material thats low in cost.
- Withstands high temperature due to its thermosetting nature.
- Has outstanding electrical properties.
- Has low specific gravity — is strong and rigid with unusually high compressive and tensile strengths.
- Has excellent impact strength and hardness allowing its use under highly abusive conditions.
- Its dimensional stability and unusual chemical inertness allow its use where other materials fail.
- Readily machinable to extremely close tolerances.
- Available as centerless ground rods in any diameter up to 1". Also cast in larger diameter rods and sheets.
- ***Write today for technical bulletins and samples. Our engineering staff is always at your disposal.***

Manufacturers of Non-strip wire, High Temperature Electrical Tubing and other extruded plastic products.

THE REX CORPORATION

54 LANDSDOWNE ST. CAMBRIDGE, MASS.

The leaders specify *Tensolite*

MINIATURE
FLEXIBLE INSULATED
WIRE & CABLE

CABLES { TWISTED, PARALLEL, BRAIDED

BARE COPPER, TINNED COPPER, SILVER PLATED } **SHIELDS**

BRAIDS { COTTON, NYLON, PLASTIC*

*TENSOLITE'S exclusive plastic film-covered Fiberglas

NEW! A LABORATORY-SIZE KIT OF MINIATURE WIRES

Includes: HOOK-UP WIRES, SHIELDED LEADS, 2, 3 and 4 WIRE CABLES, TWELVE ITEMS BETWEEN AWG 22 and 30, 2000 FEET TOTAL, REFILLS AVAILABLE

TWELVE OF THE MOST WIDELY USED MINIATURE WIRES AND CABLES

A dozen different items purposely selected for laboratories and prototype engineers to meet a multitude of today's development requirements. Don't delay —order at once. Send check or money order.

$29.50 POSTPAID

Leading engineers specify TENSOLITE Miniature Wire and Cable

because- miniaturization programs demand *less* weight, *less* space and *greater* flexibility. Only TENSOLITE is devoted exclusively to this field — assuring you of *faster* service, *lower* cost, *supreme* quality, *advanced* design and know-how, and specialized facilities.

• Free wire samples and information on request. Special constructions made to your specifications.

TENSOLITE
INSULATED WIRE CO., INC.
196 MAIN STREET, TARRYTOWN, N. Y.
Tarrytown 4 2616

HIGHER ATTENUATION
. . . at no greater cost

Built to match the most exacting requirements for radio interference reduction, ACE SCREEN ROOMS cost little or no more than home-made rooms of far lower filtering and shielding efficiency. Used and approved by leading laboratories and plants.

SCREEN ROOMS

READY-BUILT • READY TO INSTALL

- ✓ Provide attenuations of 100 to 140 db. —at frequencies from 0.15 to 10,000 mc.
- ✓ Easy to install—easy to move to a new location or to enlarge.
- ✓ Fully proved in more than 6 years of use.
- ✓ Standard and special types available for every need.

SHIELDED ACE ROOMS PHILA., PA.

ACE ENGINEERING and MACHINE CO., INC.
3644 N. Lawrence St. Philadelphia 40, Pa.
Telephone: REgent 9-1019

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 112A)

A Survey of Advertising Preferences of Members of The Institute of Radio Engineers

In December, 1950, the Advertising Department of the Institute initiated a survey to determine what advertisements were most acceptable and helpful to the membership—and why.

To obtain the information a Post Card (see illustration) was mailed to a portion of the membership representing a good cross-section of the country. This will be done each month, until the entire roster has been polled.

The reason why a member liked an advertisement fell into the following "pattern" (not necessarily in order of preference).

1. Specifications or Data.
2. Prices Quoted.
3. Application Data.
4. Engineering Drawing, Charts, Graphs, or Wiring Plan.
5. Good Visual Display—Attracts Attention.
6. Brief Yet Complete.
7. Dignified Presentation.
8. Generally Informative or Instructive.
9. Performance Characteristics.
10. No Ballyhoo or Advertising Blurbs.
11. No Answer.
12. Definitely Negative.

Other Reasons Infrequently Given—

A. New Techniques.
B. Order Blank in Ad.
C. Physical Dimensions.
D. New Product.
E. Cut Away Drawing or Exploded View.
F. Invites Correspondence.

The recipient of the card is requested to make a choice for the specific month, and then to state the reason for selection. Next, to choose an advertisement from the IRE Directory. Thirdly, to state his type of business; and last, to tell us if (A) he makes purchases, (B) sets specifications, (C) can influence buying, (D) has no interest in buying. Each of the last group is given a numerical value which is totaled to obtain a "point evaluation" of the men who prefer the ad.

This is the result of the September study. (10th report)

This is the final monthly report. A comprehensive report listing the total number of votes cast for each firm, the primary reason for advertisement selection and a total of evaluation will be given.

Various comments will be made, and from them the advertisers and their agencies should be able to draw helpful conclusions to assist in planning future material.

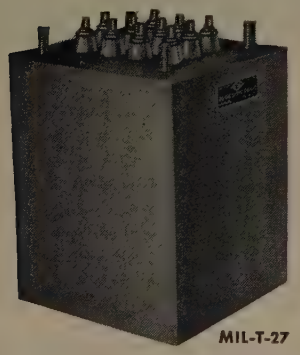
(Continued on page 116A)

SMALL TRANSFORMERS

Reactors or miniature transformers produced to high quality specifications in production line quantities.

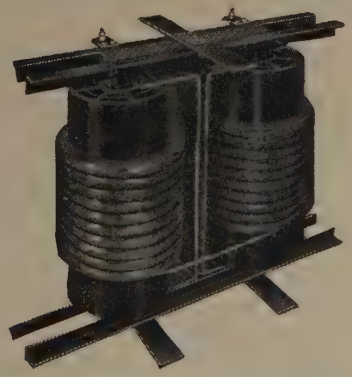
Hermetically sealed type transformers to specifications.

MEDIUM SIZE TRANSFORMERS



MIL-T-27

LARGE TRANSFORMERS



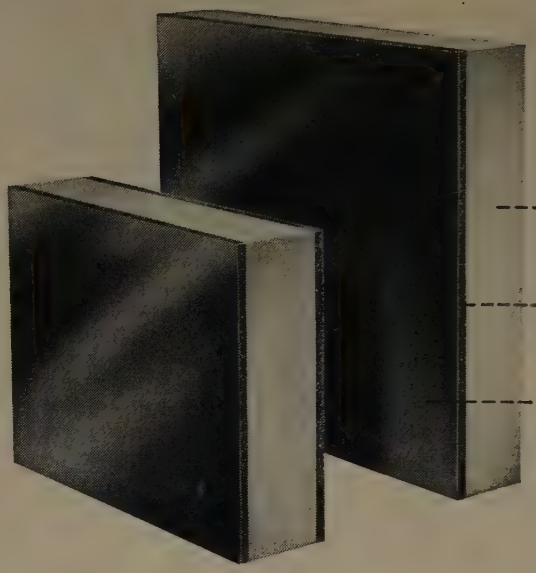
Transformers up to 225 KVA are built with attention to detail perfection to assure high performance, long-life service.

ACME ELECTRIC CORP.

4412 Water St. Cuba, N. Y., U. S. A.

Acme Electric TRANSFORMERS

CHEMELEC MULTI-BOND



Metal Faced TEFLON*

● Here is the answer to the bonding and hermetic sealing of dielectric materials to metal components.

Chemelec Multi-Bond is metal faced pure or filled TEFLON, produced by an exclusive (patents pending) method of uniting fluorocarbon resins and metals with an interlocking bond unaffected by severe mechanical shock, vibration and unequal rates of thermal expansion.

The bond is micro-crystalline in structure and gradually changes from dielectric to metal, the conducting metal surface being applied by electro-deposition or other conventional means.

Facing metals include practically all the ferrous and non-ferrous metals, the ferro magnetic group and the precious metals.

Sheets are available, metal faced on one or both sides, in thickness from .034 to 1.75 in. and in sizes up to 36 in. square.

Write for Bulletin MI-424.

**du Pont's trademark for its tetrafluoroethylene resin.*

UNITED STATES GASKET COMPANY

FLUOROCARBON PRODUCTS DIVISION

611 N. 10TH STREET, CAMDEN, N.J.

FOREMOST FABRICATORS OF "TEFLON" AND OTHER FLUOROCARBON PLASTICS

Distinguished by

BRILLIANT PERFORMANCE

Recording engineers have learned to rely on Ampex for top performance in both the audio and instrumentation fields. Mechanical flexibility and reliability, incorporated into Ampex Recorders, are a bulwark to their unequalled performance. Through long gruelling hours of continuous service the precision built Ampex delivers reliable performance with minimum upkeep time . . . that's why Ampex has unchallenged leadership.

Exclusive INTERCHANGEABLE TAPE Feature

How well Ampex has learned to build unrivaled accuracy into its products is well proven by the *interchangeable tape feature*. Ampexed tape plays back on any Ampex Recorder with the same timing and response as it would on the machine that made the original recording!

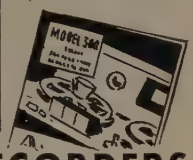
- **CONSOLE**
- **PORTABLE in twin cases**
- **RACK MOUNTING**

MODEL 300
15 & 7½ Ins. Per Sec. For audio recording to 15,000 cycles.

MODEL 301
30 & 15 Ins. Per Sec. For frequencies to 15,000 cps. Simplifies program editing.

MODEL 307
60, 30 & 15 Ins. Per Sec. For instrumentation uses to 100,000 cps.

Complete Specifications and other useful information is available without obligation on request.



STANDARD OF THE GREAT RADIO SHOWS

AMPEX

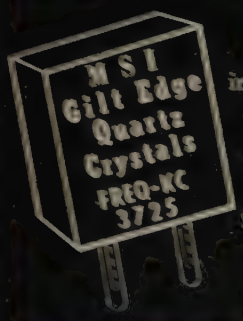
MAGNETIC TAPE RECORDERS

AMPEX ELECTRIC CORPORATION • Redwood City, Calif.

Distributors in Principal Cities

AX-97

Quartz Crystals



Made to your specific specifications. Accurate to the minutest tolerance. Exacting in performance—with thorough dependability.

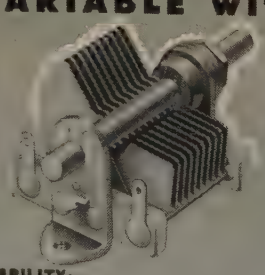
Whether one or a million, you get prompt shipment. Made by craftsmen with a quarter century experience.

Send us detailed description and quantity for prices.

MICHAEL STAHL, Inc.
215 Fulton Street New York 7, N. Y.

Now—A TIME PROVED VARIABLE with JOHNSON STANDARDS

TYPE "R" CONDENSERS ★ Capacity range 20 to 320 mmf. ★ Nickel plated brass plates .0226" ★ Spacing .020", .060" and .080" ★ Full soldered construction ★ 1/4" brass shaft and heavy brass end plates nickel plated ★ Steatite insulation ★ Silver plated beryllium copper rotor contact ★ Uniform torque.



AVAILABILITY: Plant capacity still available for production quantity orders. If you lack commitments on your unfilled requirements, perhaps we can help.

E. F. JOHNSON CO. Waseca, Minnesota

Advertising Preference Survey

(Continued from page 114A)

Firm & Page	Vote	Ans.	Value
General Radio Co. Cover IV	20	1	60
Hewlett-Packard Co. Page 27A	8	1	21
Allen B. DuMont Labs., Inc. Page 60A	6	1 & 5	11
General Electric Co. Pages 6A & 7A	5	5	14
Radio Corp. of America Page 32A	5	1 & 8	11
Raytheon Mfg. Co. Page 41A	5	1	14
Simpson Electric Co. Page 51A	5	5	15
National Carbon Co. Page 35A	4	5 & 8	10
Tektronix, Inc. Page 38A	3	5	8
Chicago Tel. & Supply Pages 56A & 57A	2	1	6
Erie Resistor Corp. Page 23A	2	5	4
Fairchild Camera & Instr. Page 10A	2	3 & 8	6
International Resistance Corp. Pages 24A & 25A	2	1 & 5	6
Ohmite Mfg. Co. Page 29A	2	5	7
Servomechanisms, Inc. Page 71A	2	5	6
United Transformer Co. Page 13A	2	1	8

Ads from September Proceedings of the I.R.E. are listed above. Choices from the 1950 IRE Directory below.

Hewlett-Packard Co. Pages 236A & 237A	8	Directory
Mycalex Corp. of America Catalog Sect.	6	Directory
General Radio Co. Pgs. 234A & 235A & Cover IV	5	Directory
Automatic Elec. Co. Catalog Sect.	3	Directory
Raytheon Mfg. Co. Catalog Sect.	3	Directory
Truscon Steel Co. Page 119A	2	Directory

NOTE: *Vote* indicates total votes.

Ans. indicates the answer most frequently given, or in a tie, both.
Value indicates point evaluation total of voters.
Directory refers to the IRE Directory.

POST CARD

Here is my vote on THE MOST INTERESTING AND USEFUL AD in [illegible] "Proceedings of the I.R.E."

Advertisement of Firm (name) GENERAL RADIO CO.

Why I liked it. BECAUSE of LAYOUT, PICTURE of INSTRUMENT, SPECIFICATIONS AND PRICE.

In the IRE DIRECTORY I also liked the ad of MYCALEX CORP.

(No signature necessary) For evaluation

My kind of business is: OSCILLOGRAPHS

( ) I buy; (✓) I set "specs." ( ) I can influence buying

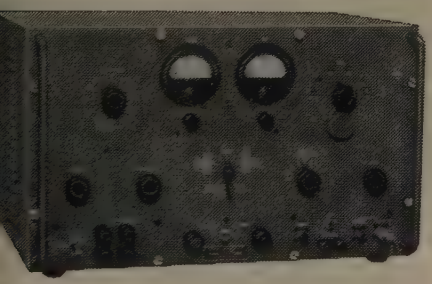
( ) I have no interest or part in buying for my work

More than one reason was given by most men as the basis for selecting an ad. To avoid making a prejudiced selection, the researcher took the first reason in 90 per cent of the answers, on the basis that the most important factor would be stated first. This may be a fallacy, however, interpretation was avoided, in an attempt to be factual.

(Continued on page 118A)

Check up ✓ CHECK OUT

WITH SIGNAL GENERATORS by AIRCRAFT RADIO Corporation



TYPE H-14 108-132 MEGACYCLES

Standard signal source for complete testing of VHF airborne omnirange and localizer receivers in aircraft or on the bench is ARC's Type H-14 Signal Generator. It checks up to 24 omni courses, omni course sensitivity, to-from and flag-alarm operation, left-center-right on 90/150 cycle and phase-localizers, and all necessary quantitative bench tests. Permits quick, accurate, check-out of aircraft just before take-off. For ramp checks RF output 1 volt into 52 ohm line; for bench checks, 0-10,000 microvolts. AF output available for bench maintenance and trouble shooting.

Price $885.00 net, f.o.b. Boonton, N.J.

Type H-12 VHF Signal Generator 900—2100 mc—source of cw or pulse amplitude-modulated RF. Power level 0 to —120 dbm. Internal pulse circuits with controls for width, delay, and rate, and provision for external pulsing. Frequency calibration better than 1%. Built to Navy specs for research, production testing. Equal to Military TS-419/U.

ARC

Price: $1,950.00 net f.o.b. Boonton, N.J.

AIRCRAFT RADIO CORPORATION
Boonton New Jersey
Dependable Electronic Equipment Since 1928

steatite, ceramic & lava insulators

for electrical and electronic applications

Custom-molded, extruded or machined to close tolerances to meet your exact specifications. Prompt delivery at low cost on large or small orders. Over half a century of service is your guarantee of complete satisfaction.

FIND OUT TODAY. Illustrated bulletin with complete technical data will be sent on request.

M. KIRCHBERGER & COMPANY, INC.

Established 1890

1424 37th Street, Brooklyn 18, New York • GEdney 6-1144
West Coast Representative:
S. Siegel, 1145 So. La Cienaga Blvd., Los Angeles 35, Calif.

NRK
Microwave Assemblies, Radar Components, and Precision Instruments . . . manufactured to your Blueprints and Specifications.
N.R.K. MFG. & ENGINEERING CO.
5644-50 NORTH WESTERN AVENUE • CHICAGO 45, ILL. • LOngbeach 1-6973

FOR YOUR PANEL

DIALCO

A NOVEL and UNIQUE CIRCUIT INDICATOR

DESIGNED FOR NE-51 NEON LAMP
For 110 or 220 volt circuits

The required resistor is
an integral part of this assembly
—"built-in."

RUGGED • DEPENDABLE
LOW IN COST

PATENTED: No. 2,421,321
Cat. No. 521308-997

WILL *YOU* TRY A SAMPLE?

Write on your company letterhead. We will act at once.
No charge, of course.

SEND FOR THE 192 PAGE HANDBOOK OF PILOT LIGHTS

Among our *thousands of Pilot Light Assemblies* there is one which will fit *your special conditions.* Many are especially made and approved for *military* use. We pride ourselves on prompt deliveries—*any quantity.*

ASK FOR OUR APPLICATION ENGINEERING SERVICE

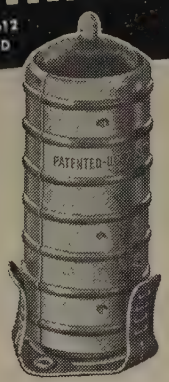
Foremost Manufacturer of Pilot Lights

The DIAL LIGHT COMPANY of AMERICA

900 BROADWAY, NEW YORK 3, N. Y. SPRING 7-1300

The New STAVER
MINI-SHIELD

U. S. PATENT NO. 2,499,612
TRADE MARK REGISTERED



The shield that fits all Miniature Tubes

A flexible shield that snugly fits all miniature tubes because it compensates for all variations in tube dimensions. Mini-Shields are made for both T5½ and T6½ bulb tubes. Send for catalog sheet.

THE Staver COMPANY INCORPORATED

91 PEARL ST. • BROOKLYN 1, N. Y.
ULSTER 5-6303

ELECTRONICALLY REGULATED
LABORATORY POWER SUPPLIES

RACK MODEL 32

• STABLE
• DEPENDABLE
• MODERATELY PRICED

STANDARD RACK MOUNTING
PANEL SIZE 10½" x 19"
DEPTH 9"
WEIGHT 38 LBS

- **INPUT:** 105 to 125 VAC, 50-60 cy
- **OUTPUT #1:** 200 to 325 VDC at 300 ma regulated
- **OUTPUT #2:** 6.3 Volts AC CT at 5A unregulated
- **OUTPUT #3:** 6.3 Volts AC CT at 5A unregulated
- **RIPPLE OUTPUT:** Less than 10 millivolts rms

For complete information write for Bulletin G2

LAMBDA ELECTRONICS
CORPORATION
CORONA NEW YORK

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 116A)

Oscillosynchroscope

Browning Laboratories, Inc., 750 Main St., Winchester, Mass., announces the new Models ON-5A and ON-5X Oscillosynchroscopes. Both instruments feature a sweep system which may be operated in either triggered or recurrent fashion with direct reading panel calibrations of sweep speed. Sweep writing rates are continuously variable from 1.0 microsecond per inch to 25,000 microseconds per inch. Vertical amplifiers are flat within ±3 db from 5 cps to 5 mc with a maximum sensitivity of 0.15 p. to p. volts per inch. Horizontal bandwidth is from dc to 500 kc.

A vertical deflection calibration source of 0–2, 0–20, and 0–200 volts provides a means for determining amplitude of vertical input voltages.

Model ON-5X is identical to Model ON-5A except for a 0.45 microsecond signal delay line which permits the display of the leading edge of a pulse which is used to trigger the sweep.

Dimensions are: Height: 14½ inches, Width: 10 inches, Depth: 16¾ inches.

25-50 MC Mobile Radio

General Electric Co., Electronics Park, Syracuse, N. Y., has announced a new 25–50 mc mobile radio communications equipment for operation in both 20 kc and 40 kc channel widths, and featuring quadra-tuned intermediate frequency transformers in the receivers.

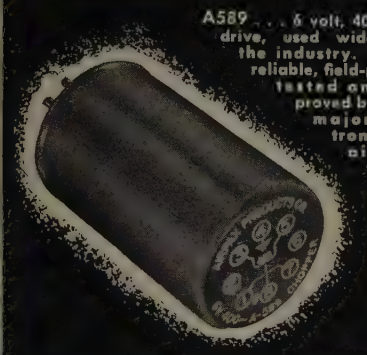
In addition, separate models are available for operation in either 20 or 40 kc channels, and the wide band equipment can be converted to 20 kc operation, with three standard capacitors and three standard resistors.

Five high Q-tuned circuits between the antenna and first converter improve reception and reduce interference. Using the 20 db quieting method, the receiver for 20 kc operation has selectivity of 100 db down at ±20 kc. By the same method, the 40 kc receiver has selectivity of 100 db down at ±30 kc.

(Continued on page 120A)

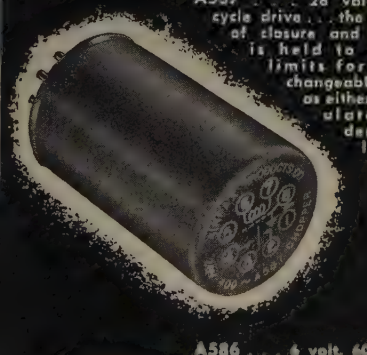
PRECISION-BUILT
CHOPPERS
YOU CAN DEPEND ON!

made by AIRPAX . . . pioneers in the field!



A589 . . . 6 volt, 400 cycle drive, used widely by the industry. Highly reliable, field-proven, tested and approved by many major electronic and aircraft firms.

A580 . . . 120 volt, 400 cycle drive, supplied to 0 phase angle or with 80° to 90° lag. Most versatile . . . repeated tests show life in excess of 1000 hours.



A587 . . . 26 volt, 400 cycle drive . . . the phase of closure and break is held to close limits for interchangeable use as either modulator or demodulator.

A586 . . . 6 volt, 60 cycle drive, 45 phase lag. Here's a chopper so reliable that you can put it into service and forget it for thousands of hours!

AIRPAX PRODUCTS COMPANY
DESIGNERS ENGINEERS

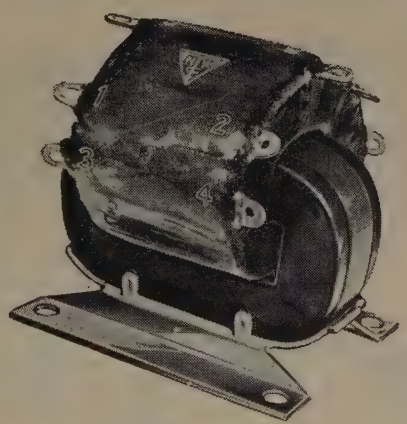
BOX 137, BALTIMORE 20, MD.

FULL RANGE OF MIL-T-27 TRANSFORMERS

HERMETICALLY SEALED UNITS

NYT hermetically sealed transformers are available in all standard sizes to meet MIL-T-27 specifications, and especially designed constructions for a wide variety of military as well as civilian applications. Designed and built to meet the most exacting specifications. Production facilities for quantity production of all sizes.

the HORNET



HORNET transformers, pioneered by NYT, are of open type construction, utilizing Class H insulating materials. Approximately one-fourth the size and weight of comparable Class A units. Filament and plate supply transformers and chokes. Units can be designed for ambients up to 190 deg. C., altitudes up to 60,000 feet; power ratings from 2VA to 5KVA.

POWER, AUDIO, FILAMENT and PLATE TRANSFORMERS
REACTORS • FILTERS • CHOKES
TV • RADIO • ELECTRONICS

NYCE

Engineering and development facilities

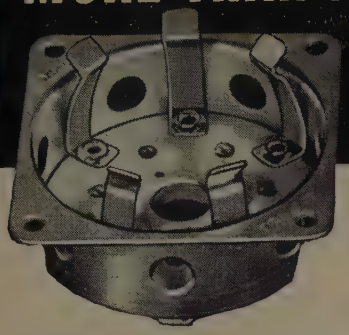
NEW YORK TRANSFORMER CO., INC.
ALPHA, NEW JERSEY

MORE THAN A TUBE SOCKET...

JOHNSON 122-101

A Basic Sub-Assembly

FOR VHF

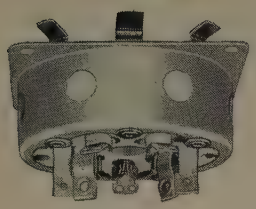


Here's one of the most popular transmitting tube sockets for VHF in America today — the JOHNSON 122-101.

It's especially designed for VHF and UHF use with Septar based tubes, such as the 826, 829, 832 and 4D32.

The 122-101 is a 7-pin steatite wafer socket incorporating ventilated base shield. Five tube retainer springs grip the tube securely even under severe conditions encountered in mobile operation.

Steatite insulation, silver-plated contacts that are recessed to prevent movement, and the ventilated base shield permit Septar based tubes to be operated at full input with maximum efficiency at their high frequency limits. Mounting holes are .185" on 2-5/16" square.



Provision for mounting button mica capacitors directly to socket. Special contacts permit mounting grid coils directly on terminals. Ventilated aluminum base shield recesses socket below chassis for short lead length. Two holes provided for mounting buss bar neutralizing leads.

For further information, consult E. F. JOHNSON COMPANY, the leading producer of power tube sockets in the electronics industry .

And Write for Complete Catalog.

Save production time and costs by using this modern tube socket.

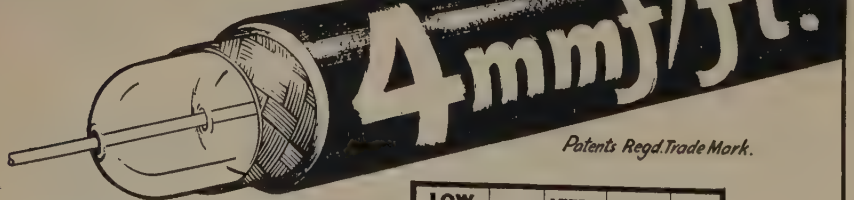
JOHNSON ... *a famous name in Radio!*

E. F. JOHNSON CO., WASECA, MINNESOTA

Only with CO-AX

AIR SPACED ARTICULATED

R.F. CABLES



Patents Regd. Trade Mark.

THE LOWEST EVER CAPACITANCE OR ATTENUATION

We are specially organized to handle direct enquiries from overseas and can give ***IMMEDIATE DELIVERIES FOR U.S.A.***

Billed in dollars Settlement by your check.

LOW ATTEN. Types.	IMPED. Ohms.	ATTEN. db100ft. of 100 Mcs.	LOADG. K.w.	O.D."	
A.1.	74	1.7	0.11	0.36	
A 2	74	1.3	0.24	0.44	
A 34	73	0.6	1.5	0.88	HIGH POWER FLEXIBLE
LOW CAPAC. Types	**CAPAC. mmf/ft.**	**IMPED. Ohms.**	**ATTEN. db100ft 100Mcs.**	**O.D."**	
C 1	7.3	150	2.5	0.36	
PC 1	10.2	132	3.1	0.36	PHOTOCELL CABLE
C 11	6.3	173	3.2	0.36	
C 2	6.3	171	2.15	0.44	
C 22	5.5	184	2.8	0.44	
C 3	5.4	197	1.9	0.64	
C 33	4.8	220	2.4	0.64	VERY LOW CAPACITANCE
C 44	4.1	252	2.1	1.03	

TRANSRADIO LTD

CONTRACTORS TO H.M. GOVERNMENT.

138A CROMWELL ROAD, LONDON S.W.7 ENGLAND

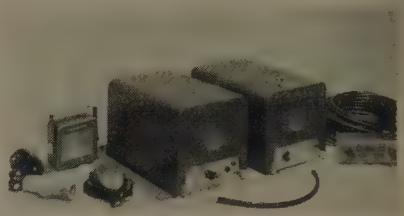
CABLES: TRANSRAD LONDON.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 118A)

The 30 watt transmitter has standby battery drain of 2.3 amperes and transmitting drain of 38 amperes at 6.3 volts. The 60 watt, 6.3 volt, transmitter has standby battery drain of 3.2 amperes and transmitting drain of 50 amperes. Receiver battery drain is 6 amperes at 6.3 volts, and 3 amperes at 12.6 volts.



For information write Dept. N-7, Inquiry Section, G-E Advertising Division, Electronics Park, Syracuse, N. Y.

Power Resistors

Dale Products, Inc., Columbus, Neb., has just released information on the miniature power resistors now being produced in their new plant in Columbus.

The "Dalohm" resistor is made in 2-, 5-, 10-, 25-, and 50-watt sizes. A special silicon material seals the resistance element making them impervious to moisture. The resistor also offers completely-welded construction from terminal to terminal. Standard tolerance is 1 per cent. However, if the occasion demands, tolerances as high as 0.05 per cent can be furnished.

The temperature coefficient is substantially flat. The resistance shift is less than 0.00002 per cent per degree centigrade.

Transmission Measurement Equipment

The Daven Co., 191 Central Ave., Newark, N. J., announces the availability of the Type 12A transmission-measuring or gain set, an ac operated, rack-mounted

(Continued on page 122A)

ZOPHAR
---WAXES
---COMPOUNDS

Anti-Corona high heat-resistant compounds for Fly Back Transformers.

Waxes and compounds from 100° F to 285° F Melting Points for electrical, radio, television, and electronic components of all types.

Pioneers in fungus-resistant waxes.

Our efficient and experienced laboratory staff is at your service.

105 YEARS

ZOPHAR MILLS, INC.
112-130 26th Street,
Brooklyn 32, N. Y.

NEW! FREQUENCY AND TIME MEASUREMENTS ACCURATELY . . . CONVENIENTLY!

-using $f = \frac{n}{t}$

ANY FACTOR MAY BE MEASURED FOR FIXED VALUE OF THE OTHER

Universal 6-in-One
MEGACYCLE FREQUENCY-TIME COUNTER

Model 801
by Potter

Now, the Potter Instrument Company offers all in one equipment, the features heretofore available only in separate counting systems. Two complete counting channels, a 100 kc crystal oscillator time base and unique gating circuits are combined to provide the new FREQUENCY-TIME COUNTER.

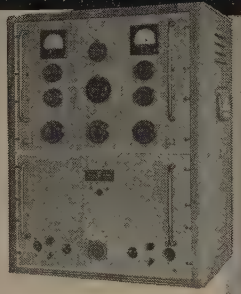
FREQUENCY MEASUREMENTS	0 to 1 mc range by counting cycles per pre-selected time or by measuring time per pre-selected count. Accuracy 0.001% minimum.
TIME INTERVAL MEASUREMENTS	0 to 10 seconds ± 10 microseconds.
FREQUENCY RATIO MEASUREMENTS	Ratio of two external frequencies can be measured.
SECONDARY FREQUENCY	100 kc crystal oscillator with divided frequencies available at 10, 1 kc and 100, 10, 1 cps.
TOTALIZING COUNTER	Six decades, pulses 0 to 1 mc, sine wave 10 cps to 1 mc.
DIRECT RPM READING TACHOMETER	Through the use of an external 60 count per revolution photoelectric disc generator an accuracy of ± 1 rpm is obtained.

Please address inquiries to Dept. 5S

POTTER INSTRUMENT COMPANY
INCORPORATED
115 CUTTER MILL RD., GREAT NECK, NEW YORK

KILOVOLTS for KLYSTRONS

A NEW UNIVERSAL KLYSTRON POWER SUPPLY FOR MICROWAVE OSCILLATORS



- Operates all low power commercial klystrons.
- Positive or negative grid operation.
- Widest modulation frequency range.
- Beam voltage: Regulated continuously variable over the ranges of 300 to 1500 volts at 65 ma. or to 3600 volts at 25 ma.
- Repeller voltage: Direct reading continuously variable over the range of −20 to −750 volts.
- Grid volts: Variable bias is provided by front panel control. "Safety-Lock" precludes tube damage.
- Modulation: Square wave, saw tooth, external or highly stable c-w operation.

WHEN YOU BUY— SPECIFY THE PRD MODEL 801-A

PRD

Polytechnic RESEARCH & DEVELOPMENT COMPANY, Inc
202 TILLARY STREET, BROOKLYN 1, NEW YORK
Offices: 55 JOHNSON ST., BROOKLYN 1, N. Y.

Test Equipment FOR RADAR and PULSE APPLICATIONS

Model 705 WOBBULATOR

. . . for RF, IF, and Video Amplifier alignment and measurement

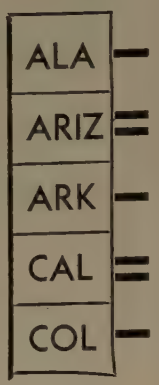
- Center Frequency of Swept Band—2.0 mc to 500 mc.
- Swept Bandwidth—up to 100 mc wide.
- Output—0.1 volt at 50 ohms, with calibrated continuously variable 90 db output attenuator to allow rapid, accurate gain measurement.
- Internal five inch CRT display of response of circuit under test; 0.05 mv. or more input to the high or low impedance probes from the circuit under test will give an adequate pattern.

Write for complete technical data

Canoga Corporation
5955 Sepulveda Blvd., Van Nuys, Calif., Box 361

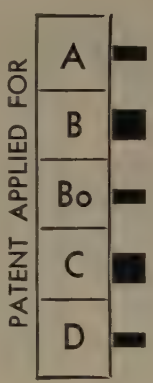
Better than ever!

Your 1951 IRE Directory is bigger and better than ever. It lists all IRE Members and provides a product index and a directory of manufacturers serving the radio-electronic industry. You will like it and use it.



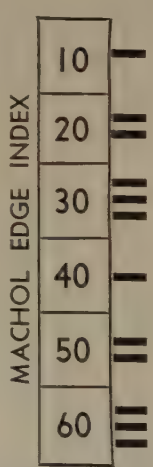
The 1951 IRE DIRECTORY uses the Machol Edge Index system for quick opening to its 76 product and service classifications, and to the alphabetical list of supply firms. This innovation adds appreciably to the ease and speed of using the DIRECTORY.

The system is illustrated above as planned in a hand-made dummy issue. A heavy separator card is inserted between the Alphabetical List of Firms, and the Product Index. This not only provides an easily found marker between the sections, but also a stiff edge for the symbols to the Edge Index marks.



Two columns of Product Index Headings are printed down the edge of this card. Each identifies a set of edge symbols. Fan the edge of the book as shown, and the Machol Edge Index symbols are revealed clearly for swiftly finding any desired classification as shown in the illustration.

This simple and practical system has all the advantages of expensive thumb cutting, or tabs such as used on a dictionary, but avoids the serious costs and publishing delays thumb cutting would require. It is covered by patent applications, and is used in our Directory on an economical royalty basis which is easily covered by the increased advertising such an improvement attracts.



The Machol Edge Indexing in the IRE Directory is part of a program of improvements constantly being made to increase the value of the Directory to every member. Special literature on the system can be obtained free by writing William C. Copp, Advertising Manager, 303 West 42nd Street, New York 18, N.Y. or phoning CI-6-3026.

1951 IRE DIRECTORY

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 120A)

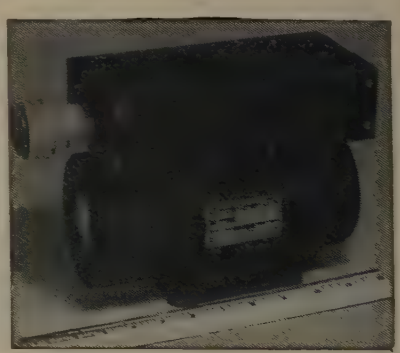
instrument designed for the measurement of voice transmission systems. Source output and receive input are 600 ohm balanced circuits, provided with dc blocking capacitors so that the equipment will not interfere with the normal operation of modern dial systems.

The oscillator consists of a 1,000 cps low distortion feed back type R-C oscillator, buffer, and associated power amplifier. The output impedance is 600 ohms resistive. The output level is +10 to −35 db adjustable in 1 db steps. The distortion and noise-out is approximately 45 db below signal level and is held at a constant ratio regardless of the output level. Controls are provided on the front panel for adjusting the 1,000 cps frequency over a range of ±30 cps, and for adjusting the oscillator level output to the red line of the meter.

The receive section consists of a high gain, wide-range amplifier, whose range is variable from +20 to −60 db, full scale meter reading, in steps of 10 db. By utilizing the meter scale, the range is increased to +20 to −80 db. Two balanced inputs are provided, 600 ohms terminating and 600 ohms bridging (6,000 ohms). The dc blocking capacitors are provided in the input circuit. Filters which provide four frequency response curves are located at the front end of the amplifier to eliminate the possibility of errors due to internal distortion in the tube circuits. A full-wave biased clipper or limiter is used to limit peak power to meter.

HF Inductor Alternator

A redesigned inductor alternator which provides from 400 to 500 cps ac from 5.5 to 230 v dc input is in production by **Carter Motor Co.**, 2644 N. Maplewood Ave., Chicago 47, Ill.



The filter has been placed on top of the frame, giving a lower overall height, more

(Continued on page 124A)

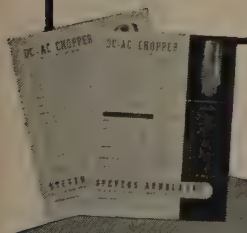
DC - AC

CHOPPER

A model for every use.
10 — 500 cycles AC
Meets AN Specifications
also 60 cycles
Single pole and double pole
Make-before-break contacts
Contacts in air or in liquid

These Choppers convert low level DC into pulsating DC or AC so that servo-mechanism error voltages and the output of thermocouples and strain gauges, may be amplified by means of an AC rather than a DC amplifier.

They are hermetically sealed, precision vibrators having special features which contribute to long life and low noise level.



WRITE FOR THESE CATALOGS . . .

#280 10-500 cycles
#246A 60 cycles

STEVENS ARNOLD INCORPORATED

22 ELKINS STREET
SOUTH BOSTON 27, MASS.
SA-4

BALLANTINE SUPER-SENSITIVE ELECTRONIC VOLTMETER

THE MODEL 310A measures 100 microvolts to 100 volts from 10 cycles up to 1 MC with 3% accuracy (and up to 2 MC with 5% accuracy) at *any* point on the single logarithmic voltage scale.

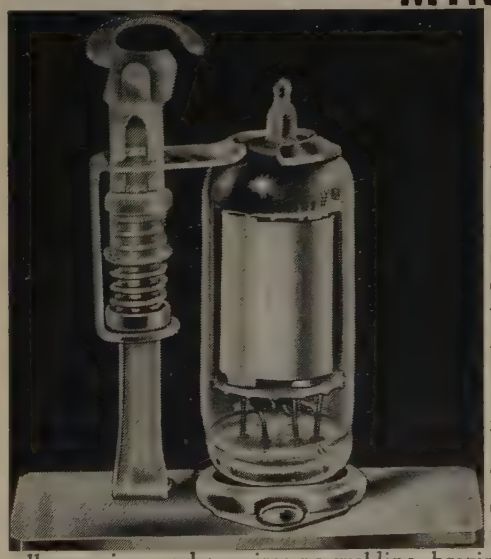
- Input Impedance is 2 megohms shunted by 15 mmfds on the 0.001 and the 0.01 ranges and by 8 mmfds on the other ranges.
- Generous use of negative feedback provides customary Ballantine stability.
- Null Detector Switch enables instrument to be used as a null balance detector in bridge measurement work down to 20 microvolts.
- Six decade range switch permits entire voltage range to be read on a single voltage scale. Linear DB Scale.
- Amplifier section may be separately used as a 60, 40 or 20 DB pre-amplifier flat within ½ DB up to 2 MC.
- Available multipliers increase the voltage range to 1,000 or 10,000 volts.
- Available precision shunt resistors permit the measurement of AC currents as low as one-tenth of a microampere.

For further information on this Voltmeter and other Ballantine Voltmeters and accessories, write for catalog.

PRICE: $235.

BALLANTINE LABORATORIES, INC.
102 Fanny Road, Boonton, New Jersey

New BIRTCHER TUBE CLAMP FOR MINIATURE TUBES

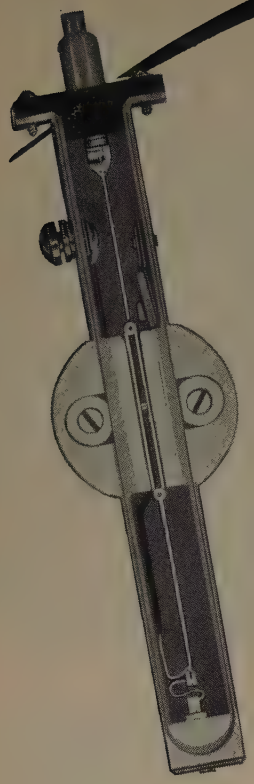


POSITIVE PROTECTION AGAINST LATERAL AND VERTICAL SHOCK!

The *New* Birtcher Type 2 Tube Clamp holds miniature tubes in their sockets under the most demanding conditions of vibration, impact and climate. Made of stainless steel and weighing less than ½ ounce, this *New* clamp for miniature tubes is easy to apply, sure in effect. The base is keyed to the chassis by a single machine screw or rivet...saving time in assembly and preventing rotation. There are no separate parts to drop or lose during assembly or during use. Birtcher Tube Clamp Type 2 is all one piece and requires no welding, brazing or soldering at any point.

If you use miniature tubes, protect them against lateral and vertical shock with the Birtcher Tube Clamp (Type 2). Write for sample and literature.

The BIRTCHER Corporation
5087 HUNTINGTON DRIVE • LOS ANGELES 32



Sensitive **Rugged**

Dependable

HEILAND GALVANOMETERS

of high current and voltage sensitivity are the heart of Heiland recorders.

Heiland galvanometers are available in natural frequencies ranging from 32 cycles per second to 4700 cycles per second. All galvanometers are electromagnetically damped with exception of those having natural frequencies above 450 cycles per second; these are fluid damped. Permanent magnet assemblies are available for mounting 2, 6, and 12 Heiland galvanometers.

dependable instruments

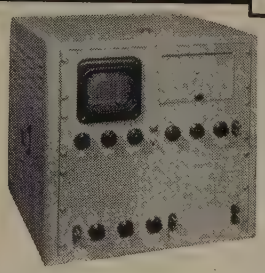
Heiland DENVER

For further information on Heiland Galvanometers, Multi-Channel Oscillograph Recorders or Associate equipment, write or wire . . .

HEILAND RESEARCH CORPORATION 130 East 5th St. DENVER, COLO.

USED AND PRAISED BY SONOTONE*

PANORAMIC'S AP-1 COMBINATION G-2

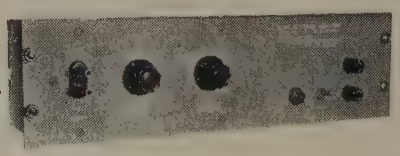


Panoramic Sonic Analyzer AP-1

Automatically separates frequency components of audio waves; measures frequency and amplitude. AP-1 tunes repetitively, once per second, through a frequency range from 40 to 20,000 cps.

* SONOTONE SAYS

"in combination the response indicator and sonic analyzer have facilitated the investigation of frequency response and signal analysis."



Panoramic Sonic Response Indicator G-2

Determines amplitude vs. frequency characteristics of systems between 40 and 20,000 cps. Used for research development or production line testing of amplifiers, speakers, filters, transmission lines, receivers.

PANORAMIC CAN FACILITATE YOUR PRODUCTION! WRITE FOR COMPLETE DETAILS TODAY.

PANORAMIC
RADIO PRODUCTS, INC.

12 South Second Ave., Mt. Vernon, N.Y.
MOunt Vernon 4-3970

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 122A)

compact design, and smaller mounting area. No windings are used in the rotor. Sliding contacts, brushes, and slip rings are eliminated. The output may be controlled with voltage regulators or by field control.

The ac rotor and field are electrically isolated from the dc end. No permanent magnets are used for power generation. Magnetic fields, vibration, and aging do not affect the equipment. A separate dc output is also available, although designed primarily for 24 to 29 volts airborne equipment, any input from 5.6 to 230 V dc is available on order.

Noise Suppression Units

Filtron Co., Inc., 131-05 Fowler Ave., Flushing, L. I., N. Y., has announced production of several different models and types of interference filters.

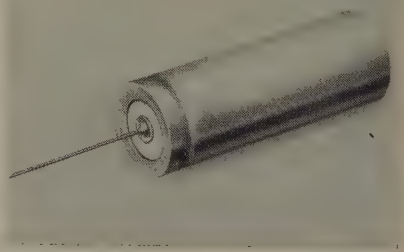
At top left is a 15 ampere, 28 v dc rf filter. This unit is hermetically sealed, has AN connectors, and has high attenuation from 150 kc to 400 mc.

The unit on the right is a 3 ampere 125 v ac, 400 cps subminiature filter. It has glass solder sealed terminals, and will operate up to 100°C.

The filter shown with the cover removed is a miniaturized 20 circuit arrangement.

Teflon Capacitor Seals

A new line of Chemelec hermetic seals for capacitor can sizes from 0.377 to 0.962 inch is now offered by the **Fluorocarbon Products Div., United States Gasket Co.,** Camden 1, N. J.



Utilizing a method of producing a fused, hermetic seal between TEFLON

(Continued on page 126A)

COMMUNICATIONS EQUIPMENT CO.

10 CM RESEARCH EQUIPMENT

COAXIAL WAVEMETER, W.E. Transmission type, using type "N" fittings. Calibrated between 3400-4500 MC $99.50
LHTR. LIGHTHOUSE ASSEMBLY. Part of RT39 APG 5 & APG 15. Receiver and Trans. Cavities w/assoc. Tr. Cavity and Type N CPLG. To Recvr. Uses 2C40, 2C43, 1B27. Tunable APX 2400-2700 MCS. Silver Plated $49.50
BEACON LIGHTHOUSE cavity 10 cm. Mfg. Bernard Rice ..... each, $47.50
MAGNETRON TO WAVEGUIDE Coupler with 721A Duplexer Cavity, gold plated $45.00
SIGNAL GENERATOR, using 417A klystron, 2700-3300 mc. Output approx. 50 mw. 115 vac power supply. With tubes, new $425.00
REGULATED POWER SUPPLY for GL 446 type lighthouse tubes (2C40, etc.) 115 vac, 60 cycles. Panel Mounting. Less tubes $32.50
RT-39/APG-5 10 cm. lighthouse RF head c/o Xmtr.-Recvr-TR cavity, compl. recvr. & 30 MC IF strip using 6AK5 (2C40, 2C43, 1B27 lineup) w/Tubes.
721A TR BOX complete with tube and tuning plungers $12.50
McNALLY KLYSTRON CAVITIES for 707B or 2K28. Three types available $4.00
TS 268 CRYSTAL CHECKER $35.00
F 29/SPR-2 FILTERS, type "N" input and output $12.50
WAVEGUIDE TO ⅞" RIGID COAX "DOORKNOB" ADAPTER CHOKE FLANGE, SILVER PLATED BROAD BAND $32.50
AN/APR5A 10 cm antenna equipment consisting of two 10 cm waveguide sections, each polarized. 45 degrees ..... per set, $75.00
POWER SPLITTER: 726 Klystron input dual "N" output $5.00
MAGNETRON COUPLING FOR TYPE 720 MAG. to 1⅛" x 3" Waveguide $35.00
ASI4A/AP-10 CM Pick up Dipole with "N" Cables $4.50
S BAND SIGNAL GENERATOR, complete with calibrated attenuator, W. E. coax. wavemeter, McNally Klystron Cavity. Regulated power supply operates from 115 V.A.C., 50-1200 Cycles. Manufactured by W. E. $650.00
OAJ ECHO BOX, 10 CM, TUNABLE $22.50

⅞" RIGID COAX—⅜" I. C.

RIGHT ANGLE BEND, with flexible coax output pickup loop $8.00
SHORT RIGHT ANGLE BEND, with pressurizing nipple $3.00
RIGID COAX to flex coax connector $3.50
STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $5.00
RT. ANGLES for above $2.50
RT. ANGLE BEND 15" L. OA $3.50
FLEXIBLE SECTION, 15" L. Male to female $4.25
FLEX COAX SECT. Approx. 30 ft. $16.50
⅞" RIGID COAX. BULKHEAD FEED-THRU $14.00

3 CM Research Equipment
1" x ½" Waveguide

1" x ½" waveguide in 5' lengths, UG 39 flange to UG40 cover .per length, $7.50
Rotating Joints supplied either with or without deck mounting. With UG40 flanges ..... each, $17.50
2J42 Magnetron Pulse Modulator, 14kw max. rating 7kw min. Plate voltage pulsed 5.5kv 6.5 Amp. 1001 duty cycle, 2.5 usec pulse length max. filament 6.3V .5 Amp. Includes magnetron mtg. and blower. Requires 3C45 and 2-3B24. New $75.00
TS 268 Crystal Checker $35.00
Bulkhead Feed-Thru Assembly $15.00
Pressure Gauge Section 15 lb. gauge and press nipple $10.00
Pressure Gauge, 15 lbs. $2.50
Dual Oscillator-Beacon Mount. P/O APS 10 Radar for mounting two 723A/B klystron with crystal mts. matching slugs, shields $42.50
Dual Oscillator, Mount. (Back to back) with crystal mount, tunable termination attenuating slugs $18.50
Directional Coupler, UG-40/U Take off 20 DB $17.50
2K25/723 AB Receiver local oscillator Klystron Mount, complete with crystal mount, Iris coupling and choke coupling to TR $22.50
TR-ATR Duplexor section for above $8.50
CU 105/APS 3I Direction Coupler 25 DB $25.00
723AB Mixer—Beacon dual Osc. Mnt. w/xtal holder $12.00
Waveguide Section 12" long choke to cover 45 deg. twist & 2½" radius. 90 deg. bend $4.50
Twist 90 deg. 5" choke to cover w/press nipple $6.50
Waveguide Sections 2½ ft. long silver plated with choke flange $5.75
Rotary Joint choke to choke with deck mounting $17.50
3 cm. mitred elbow "E" plane unplated $12.00
UG 39 Flanges ..... $ .85
UG 40 Chokes $1.00
90 degree elbows, "E" or "H" plane 2½" radius $12.50
90 degree twist 6" long $8.00
45 degree twist $8.00
40KW X BAND Radar, complete as described and illustrated in July 1951 PROC. IRE
APS-4 Under Belly Assembly, less tubes $375.00

1¼" x ⅝" WAVEGUIDE

Tunable Termination, Precision adjust $65.00
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Waveguide Lengths, cut to size and supplied with 1 choke, 1 cover. per length ..... per ft., $2.00
BI Dir-Coupler WG output calibrated—25 db nominal $17.50
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Slug. Tuner Attenuator W.E. guide. Gold plated $6.50

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D-172155	$2.25
D-172307	$1.70
D-168687	$ .95
D-171812	$ .95
D-171528	$ .95
D-162356(308A)	$1.50

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D-166283	$1.50
D-167332 (tube)	$1.50
D-170396 (bead)	$1.50
D-167613 (button)	$1.50
D-164699 for MTG "X" band Guide	$2.50

1.25 CM RESEARCH EQUIPMENT

COMPLETE 24,000 MC RF HEAD, including 2K33 Klystron, 3J31 Magnetron and Magnet, all plumbing, and associated circuitry in standard A-N pressurized housing. New $1100.00
Low Power Load $20.00
Shunt Tee $35.00
Waveguide Lengths, 2" to 6" long, gold plated with circular flanges and coupling nuts ..... per inch, $2.25
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Right Angle Bend E or H Plane, specify combination of couplings desired $12.00
45° Bend E or H Plane, choke to cover $12.00
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"K" Band Directional Coupler ..... each, $49.50

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Stainless Steel streamlining housings for above $18.50
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MAGNETO STRICTION head coil plate assembly $14.50
MAGNETO STRICTION head assy. consists of coil, plate nickle diaphragm plate, milled steel body, unassembled $65.00
SUPERSONIC OSCILLATOR RCA 17-27 Kc. Rec. Driver. Osc. 115 v 60 cy. AC. Designed for use w/200 watt driver. New less tubes $39.50
QBF SONAR mfg. WE Complete console consists of 10-40 kc. rec. driver osc. ind. & control unit, and driver amplifier 22-28 kc. Write.
QJA SONAR QBF w/OJA adapter kits w/cathode ray tube indication. Write.
SUPERSONIC OSCILLATOR: Output 50W A-1 emission, 18-25KC. Operates from 115V, 60 Cy., 1 phase, new $150.00

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APS-IC MODULATOR DECK. Complete, less tubes $75.00

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G.E. #6E3-5-2000-501P2T, 6KV "E" circuit, 3 sections .5 microsecond, 2000 PPS. 50 ohms impedance $6.50
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G.E. K2748A. Pulse Input line to magnetron $36.00
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Ray UX 8442—Pulse inversion—40v + 40v $7.50
Ray UX 7361 ..... $5.00

TEST SETS

TS 102/AP	TS 226
TS 47/APR	TS 250/APN
TS 36/AP	TS 89
TS 12 UNIT 2	I-203-A
Q. METER	TS 11/AP
TS 69/AP	BC 438
TS 56A/AP	CS60-ABW
CW60-ABM	I-158
LU-1	I-222
LU-3	I-185
TS 159	TS 268/U

Send for Further Information and Prices.

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MAGNETRONS

Tube	Frq. Range	Pk. Pwr. Output
2J27	2965-2992 mc.	275 KW
2J31	2820-2860 mc.	265 KW
2J21-A	9345-9405 mc.	50 KW
2J22	3267-3333 mc.	265 KW
2J26	2992-3019 mc.	275 KW
2J32	2780-2820 mc.	285 KW
2J38 Pkg.	3249-3263 mc.	5 KW
2J39 Pkg.	3267-3333 mc.	87 KW
2J49	9000-9160 mc.	58 KW
2J61	3000-3100 mc.	35 KW
2J62	2914-3010 mc.	35 KW
3J31	24,000 mc.	50 KW
5J30		
718DY	2720-2890 mc.	250 KW
720BY	2800 mc.	1000 KW
725-A	9345-9405 mc.	50 KW
730-A	9345-9405 mc.	50 KW
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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 124A)

(duPont's tetrafluoroethylene resin) and metal; a metal surface is applied to the outer edge and center of the seal, ready for soldering to the capacitor can, and solder-sealing the lead wire vacuum-tight.

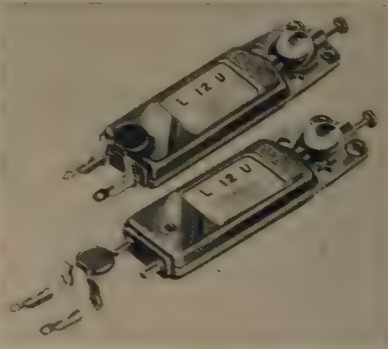
This design simplifies assembly as it eliminates exhaust vents. The center eyelet accommodates the condenser wire with a loose fit to allow exhausting prior to sealing.

Due to the elasticity of the plastic and the nature of the fused seal, Chemelec Capacitor seals have no acute strain point due to unequal rates of thermal expansion.

These seals will not dc plate. They are serviceable to temperatures from −110 to 500°F without appreciable change in electrical characteristics.

Phono Pickup

Astatic Corp., Harbor & Jackson Sts., Conneaut, Ohio, has developed the L-12-U phonograph pickup cartridge employing a capacitor harness which slips on or off the terminals to change output from a high of 4.0 volts to a low of 1.2 volts at 1,000 cps. It will serve as a replacement for more than 125 different standard 78 rpm cartridges now in use.



Another feature of the Astatic dual-output cartridge is a needle-chuck limiting principle which restricts motion of the chuck both radially and lengthwise. Purpose is to prevent dislocation of the chuck, to protect against crystal breakage from rough handling and when changing a needle.

The L-12-U cartridge is furnished with the tiny capacitor harness in position on the terminals. Installed in that manner, output is high. Slipping off the capacitor reduces output.

The range of the new cartridge is up to 5,000 cps. Minimum needle pressure is one ounce, weight of the cartridge 19 grams. The housing is stamped steel.

You won't find today's most widely used military capacitors listed in JAN!

Joint Army and Navy component specifications were never meant to limit engineering progress—and, with Sprague, they most certainly haven't!

. . . Sprague subminiature capacitors have pioneered size and weight reductions plus high-temperature operation that would have been impossible with conventional capacitors. You'll not find these unique, hermetically-sealed capacitors listed in the current issue of Joint Army-Navy specification JAN-C-25. In every case, however, they have been fully approved for use. The reason is simple: In effect, Sprague subminiature capacitors are *super*-JAN types. They greatly exceed the already high minimum quality limits established by JAN specifications.

As the long-time leader in capacitor development, Sprague clearly recognizes that its engineering obligation extends far beyond conventional standards—*so markedly so that much of today's tremendous production of Sprague components for military use is based on types for which no JAN specifications yet exist!*

Thus, to equipment manufacturers faced with the problems of reducing size and weight or of paving the way to higher temperature operation, Sprague offers help along many lines—from the subminiature capacitors shown here to Vitamin Q☆ photo-flash capacitors to Ceroc☆ 250°C. ceramic-Teflon insulated magnet wire and many others.

. . . opening new horizons to critical equipment design

You can do miniaturization jobs with these capacitors that were hitherto impossible!

Conservatively rated in designs for either 85°C. or 125°C. operation and with voltage ratings from 100 to 1000 volts, Sprague subminiature hermetically-sealed paper capacitors are available in physical sizes materially smaller than JAN types. Rigid mounting is greatly simplified by a variety of new mounting designs—also pioneered by Sprague.

For complete information write for Bulletin 213B.

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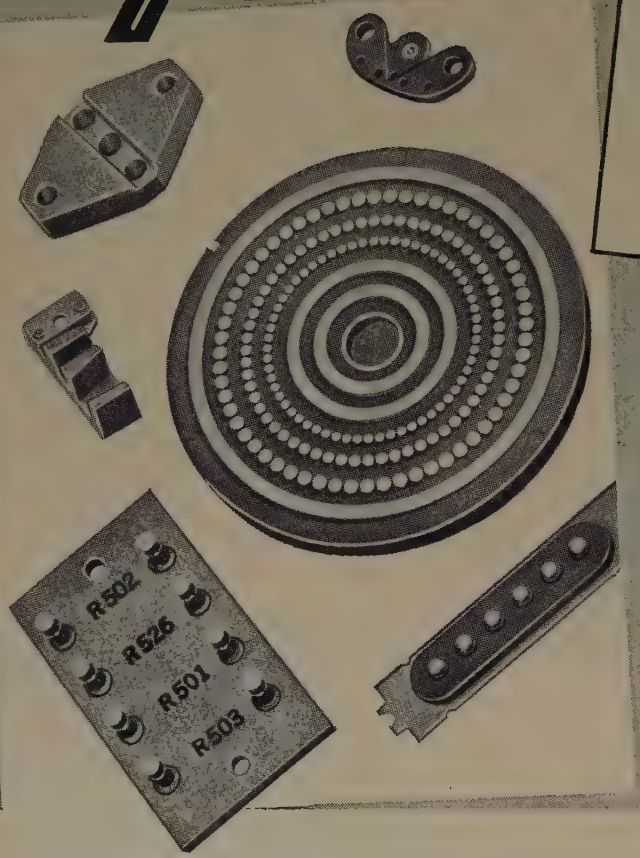

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MYCALEX GRADE	400	410	410X
POWER FACTOR, 1 MC	0.0018	0.0015	0.012
DIELECTRIC CONSTANT, 1 MC	7.4	9.2	6.9
LOSS FACTOR, 1 MC	0.013	0.014	0.084
DIELECTRIC STRENGTH, volt/mil	500	400	400
VOLUME RESISTIVITY, ohm/cm	$2x10^{15}$	$1x10^{15}$	$5x10^{14}$
ARC RESISTANCE, seconds	300	250	250
MAX. SAFE OPER. TEMP., °C	370	350	350
WATER ABSORPTION % 24 hrs.	NIL	NIL	NIL

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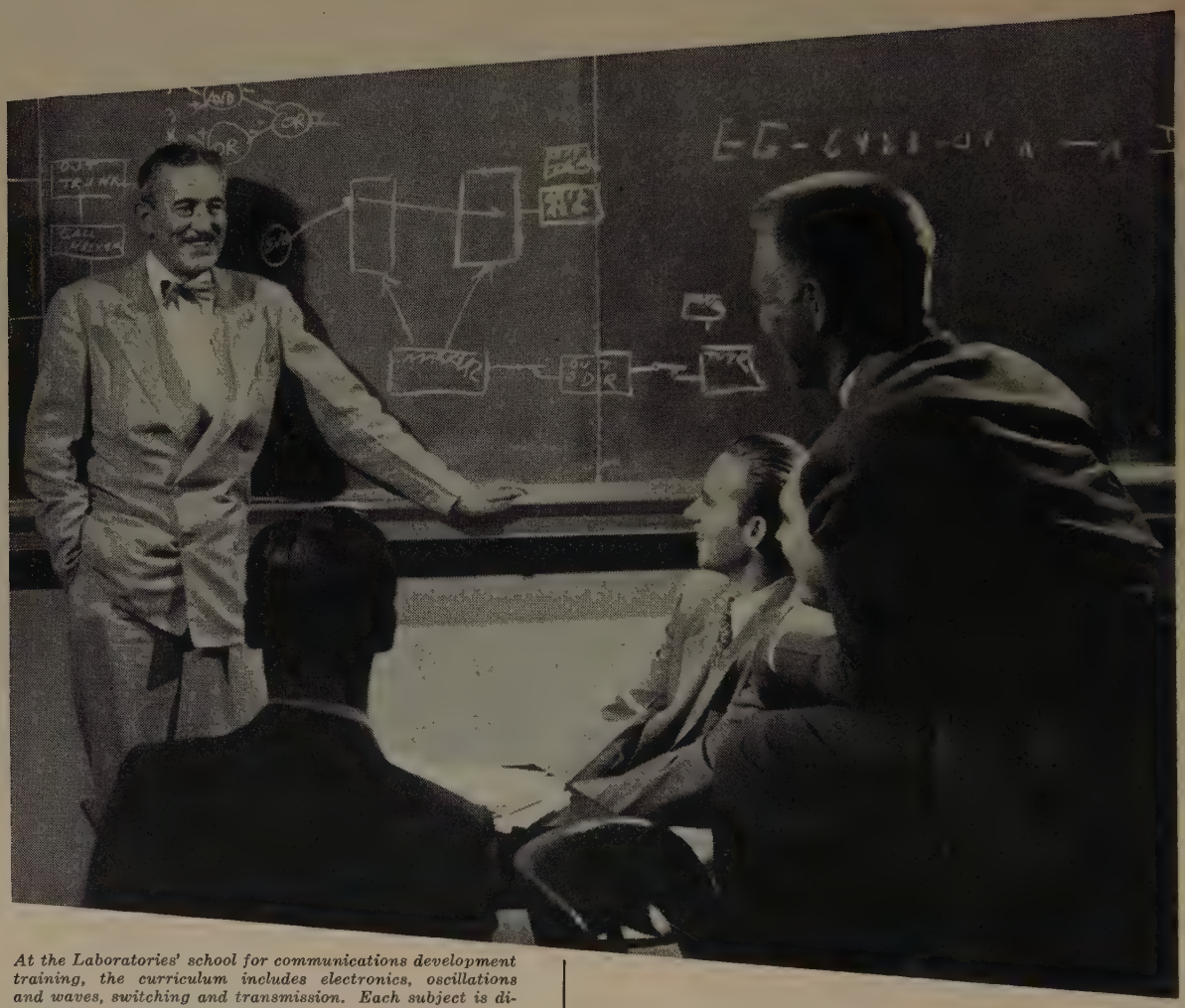

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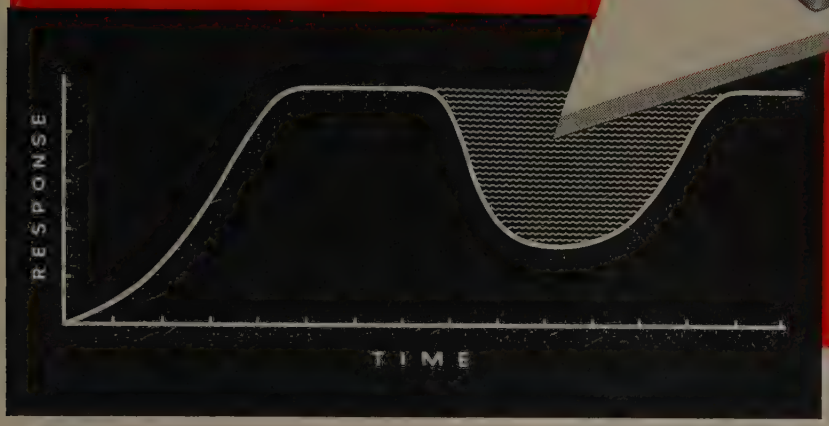

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BE SAFE, BE SURE . . . SPECIFY G-E! Broad-band gas switching tubes for microwave applications were pioneered by G-E. This research and extensive know-how stand squarely back of the new GL-6038's performance, as with other TR, A-TR, and Pre-TR types bearing the G-E name. Get up-to-the-minute information! Wire or write for Bulletin ETD-158. *General Electric Company, Electronics Division, Section 9, Schenectady 5, New York.*

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GROUP	TYPE NO.	FREQ. RANGE	MAX PEAK POWER	LEAKAGE POWER	RECOVERY TIME, MAX
TR	GL-1B63-A	8490-9578 mc	250 kw	30 mw MIN FIRING POWER	4 mu sec at —3 db LOADED Q, TYPICAL
A-TR	GL-6038	9000-9600 mc	100 kw	5 kw	4
	GL-1B35	9000-9600 mc	250 kw	5 kw	4
	GL-1B37	8500-9000 mc	250 kw	5 kw	4
	GL-1B44	2680-2820 mc	1000 kw	20 kw	4
	GL-1B56	2775-2925 mc	1000 kw	20 kw	4 LEAKAGE ENERGY
PRE-TR	GL-1B38	2700-2910 mc	1000 kw	100 kw	.0002 joules

GENERAL ELECTRIC

125-K7

Now! Complete coverage!

hp SIGNAL

5 precision instruments. Continuous frequency coverage. Frequency, output set and read directly. Wide choice of modulation, pulsing, delay and synchronizing. Superior resetability. Broad applicability.

New -*hp*- Model 618A SHF Signal Generator

Now –*hp*– offers the world's broadest, easiest-to-use line of VHF, UHF and SHF signal generators. These are precision instruments supplying accurately known frequencies up to 7,600 mc. They are deliberately designed for utmost convenience and accuracy in making all kinds of measurements including: receiver sensitivity, selectivity or rejection; signal-noise ratio, conversion gain, SWR, antenna gain, transmission line characteristics; and for driving bridges, slotted lines, filter networks, etc.

New –*hp*– Model 618A, shown above, is for use in the 3,800 to 7,600 mc band. It provides a 1 milliwatt signal into a 50-ohm coaxial load (zero dbm). Its output attenuator reduces output level to less than —100 dbm. Frequency is continuously variable, directly read in mc. Repeller voltage tracks automatically; no adjustment is needed to select the correct frequency. Accuracy is ½ of 1%. The instrument offers external frequency modulation with maximum deviation of ± 10 mc. It also may be externally pulse modulated, with a positive or negative peak of approximately 15 volts. Internal square wave modulation is also provided; frequency range, 400 to 1,000 cps. $2,250 f.o.b. factory.

For complete details, write factory direct or see the -hp- sales representative in your area.

HEWLETT-PACKARD COMPANY

2159D Page Mill Road • Palo Alto, California

Sales representatives in all principal areas. Export: Frazar & Hansen, Ltd., San Francisco, Los Angeles, New York

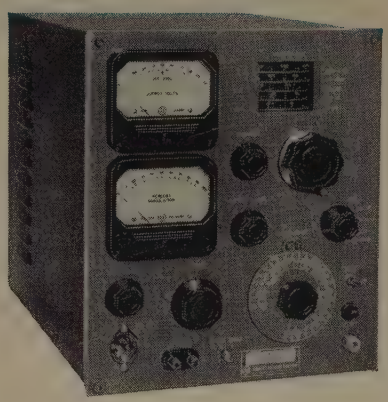
HEWLETT hp PACKARD

GENERATORS

10 to 7600 mc

10 to 500 mc -*hp*- 608A SIGNAL GENERATOR

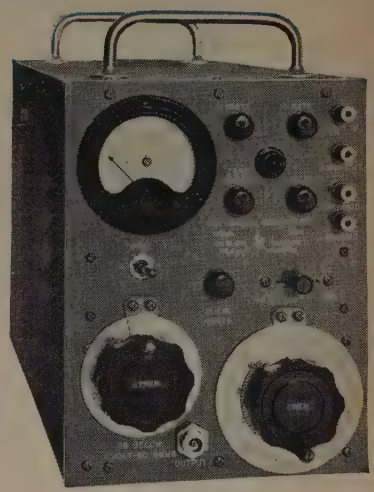
Output range 0.1 μv. to 1.0 v. into 50 ohms. Accuracy ± 1 db. Direct reading frequency and output calibration, no charts or interpolation. CW, pulsed or amplitude modulated output (50 to 1,000,000 cps). Resetability better than 1 mc. Master oscillator power amplifier for widest modulation capabilities. Constant internal impedance 50 ohms. Maximum VSWR 1.2. $850 f.o.b. factory.



-*hp*- Model 608A

450 to 1,200 mc -*hp*- 610B SIGNAL GENERATOR

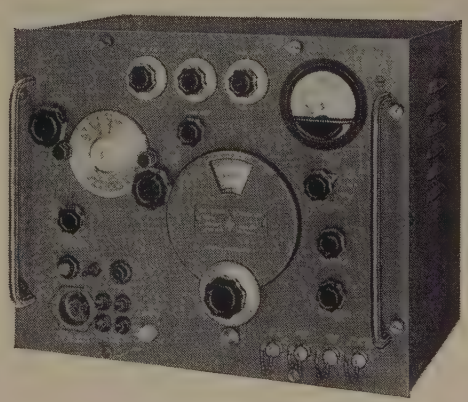
Output range 0.1 μv. to 0.1 v. into 50 ohms. Accuracy ± 1 db. Output and frequency directly set and read, no charts or interpolation. Modulation: internal or external pulsed, external amplitude, external square wave. Widely variable pulse length, repetition, and delay features. $925 f.o.b. factory.



-*hp*- Model 610B

800 to 2,100 mc -*hp*- 614A SIGNAL GENERATOR

Output range 0.1 μv. to 0.223 v. (1 mw). Accuracy ± 1 db. Single dial direct reading frequency and output, no charts or interpolation. CW, pulsed and FM output. Modulation: internal pulsed, FM, external pulsed. Widely variable pulsing, synchronizing, delay and triggering features. Extremely fast rise/decay time 0.1 μsec. Constant internal impedance 50 ohms, SWR 3 db. $1,950 f.o.b. factory.



-*hp*- Model 614A

1,800 to 4,000 mc -*hp*- 616A SIGNAL GENERATOR

Output range 0.1 μv. to 0.223 v. (1 mw). Accuracy ± 1 db. Single dial, direct reading frequency and output, no charts or interpolation. Output, modulation, and synchronization features identical with Model 614A. Like Model 614A, instrument automatically tracks frequency changes, requires no voltage adjustment during operation. $1950 f.o.b. factory.

-*hp*- Model 616A

HEWLETT hp PACKARD

special **HARNESSES, CABLES, CORDS** *for Military equipment*

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If you have a wiring problem on any of your Defense Projects, consult Lenz. Here is a dependable source for Harnesses, Cables and Cords, constructed of JAN-C-76 Approved Wire, that can speed up your assembly operations.

LENZ ELECTRIC MANUFACTURING CO.

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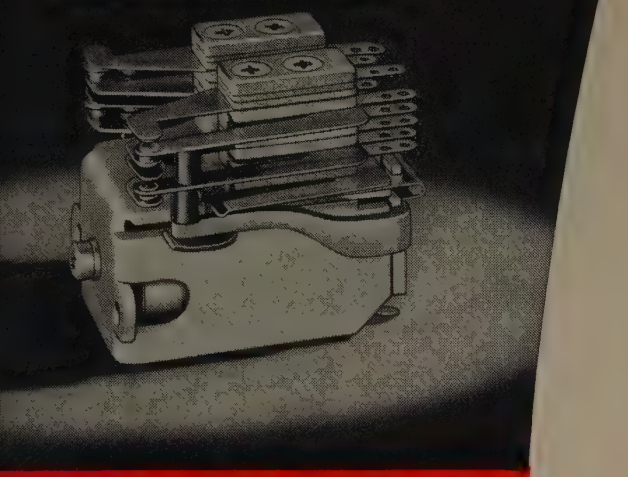
THE *New* CLARE TYPE "N" RELAY...

a small, highly sensitive relay designed for efficient operation on low power*

CLARE Type "N" RELAY



SPECIFICATIONS of CLARE Type "N" RELAY

COIL
Single- or double-wound. Double wound coils are concentric and have four terminals, two for each winding.

OPERATING VOLTAGE
Up to 180 volts dc.

ARMATURE
Single- or double-arm. Armature has high lever ratio (approx. 3:1) and no air gap.

CONTACT ASSEMBLY
Forms A to C. Maximum of 10 springs per pileup.

CONTACTS
Code No. 4 standard unless load conditions require different contact material.

TERMINALS
All located at armature end of relay.

DIMENSIONS
Length: 1⅝", Width: 1$\frac{5}{32}$", Height: Min. (with two contact springs): 1$\frac{1}{16}$"; Max. (with ten contact springs): 1⅝".

NET WEIGHT
Single-arm, 2¼ oz. (approx.); double-arm, 3 oz. (approx.).

MOUNTING
Two #5-40 tapped holes on $\frac{13}{16}$" centers. Located so mounting screws cannot foul coil.

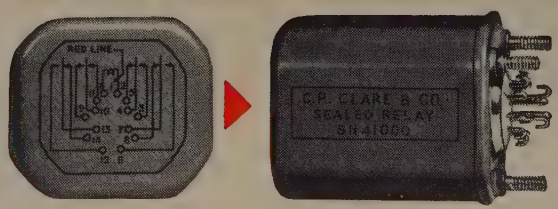
CLARE Type "N" Relays are designed for operation on extremely low power. A close-coupled magnetic circuit, generous use of magnetic iron, and unusually efficient coil design give high sensitivity while retaining high contact pressure (minimum 30 grams) and adequate contact gap (minimum 0.015").

Other important advantages include small size, light weight, and especial adaptability to hermetic sealing. Type "N" Relays having not more than 14 terminals for coil and contact springs can be hermetically sealed in enclosures of extremely small size.

For more detailed information on Clare Type "N" Relays you are invited to write for Bulletin No. 109. Clare sales engineers are located in principal cities. Call them or write C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials, Ltd., Toronto 13. Cable Address: CLARELAY.

*With a 10,000-ohm coil, 1 Form C contact (spdt), and a standard adjustment, this relay will operate on less than 50 milliwatts. With a 450-ohm coil and four Form C contacts (4pdt), it will operate on 7/10 watt, even under conditions of vibration and high ambient temperature.

Clare Type "SN" Hermetically Sealed Relay



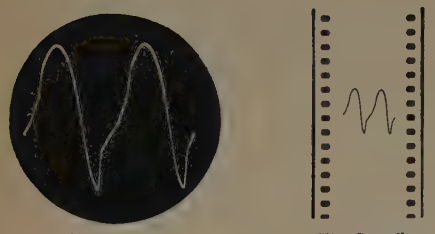
Shown above is one of the hermetically sealed steel enclosures in which the Type "N" Relay can be sealed. Dimensions are: Length: 1-7/16"; Height: 2-1/16"; Width: 1⅝". Net weight of relay having 12 contact springs, six in each pileup, is 5 oz. (approx.). Note connection diagram clearly and permanently imprinted on base of enclosure by silk screen process.

Write for CLARE Bulletin No. 109

CLARE RELAYS

First in the Industrial Field

How much can you expect an oscilloscope camera to do?

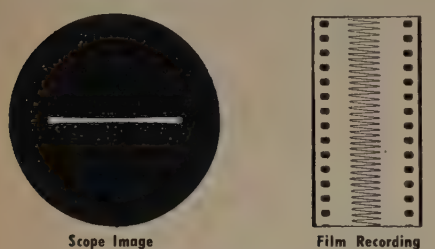


Scope Image — Film Recording

1. Single-frame photography of stationary patterns using a continuously running sweep.

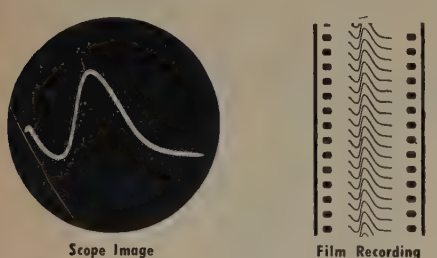
Scope Image — Film Recording

2. Single-frame photography of single transients using a single sweep.



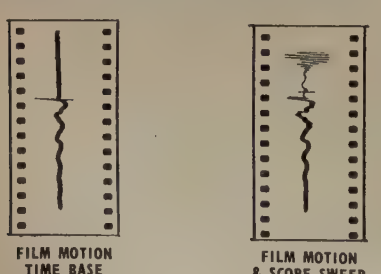
Scope Image — Film Recording

3. Continuous-motion photography employing film motion as a time base.



Scope Image — Film Recording

4. Continuous-motion photography employing oscilloscope sweep as a time base.



FILM MOTION TIME BASE — FILM MOTION & SCOPE SWEEP

5. Continuous-motion photography employing combination of film motion and oscilloscope sweep as a time base.

It's only reasonable that you should expect the oscilloscope camera you buy to record what you see on an oscilloscope screen during any period. But can it be expected to do any more? We think so.

For example, did you know that the *Fairchild Oscillo-Record Camera*—our idea of the most versatile 35-millimeter oscilloscope camera now available—can GREATLY EXTEND THE USEFULNESS OF YOUR OSCILLOSCOPE?

As you know, many non-recurring phenomena occur too rapidly to permit adequate visual study. Others occur so slowly that continuity is lost. Sometimes you have combinations of very slow-speed phenomena and occasional high-speed transients. In any one of these cases, the Fairchild Oscillo-Record Camera will take over where your eye and the oscilloscope leave off.

This extremely versatile instrument is now being used daily by many hundreds of engineers in widely divergent fields. For an idea of what it can do for you, study the five scope images and recordings illustrated at left. Each solves a particular problem.

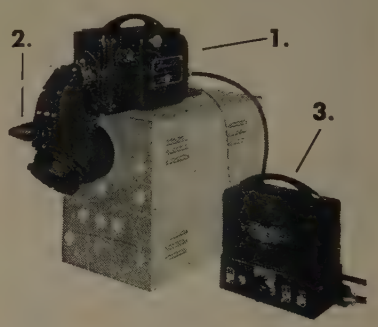
Oscillo-Record users especially like its:

CONTINUOUSLY VARIABLE SPEED CONTROL—1 in./min. to 3600 in./min.

TOP OF SCOPE MOUNTING that leaves controls easily accessible.

PROVISION FOR 3 LENGTHS OF FILM—100, 400, or 1000 feet.

For more data write *Fairchild Camera Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N.Y. Dept. 120-16CI.*



FAIRCHILD OSCILLO-RECORD CAMERA—1. camera, 2. periscope, 3. electronic control unit. *Available accessories* include external 400 and 1000 foot magazines, magazine adaptor and motor, universal mount for camera and periscope, binocular split-beam viewer.

VALUABLE RECORDS FOR IMMEDIATE EVALUATION

The Fairchild-Polaroid® Oscilloscope Camera produces a photographic print in a minute

Valuable but inexpensive oscillograms for immediate evaluation; automatic one-minute processing without a darkroom; a set up time of two minutes or less—they're just three of the many advantages that are yours when you use the Fairchild-Polaroid Oscilloscope Camera. Wherever individual exposures meet your recording requirements—where you'd like to have permanent records of the traces you're now sketching or carrying in your memory, this is the camera that can bring new speed, ease and economy to your job. Prints are 3¼x4¾ and each records two traces exactly one-half life size. Write today for details.

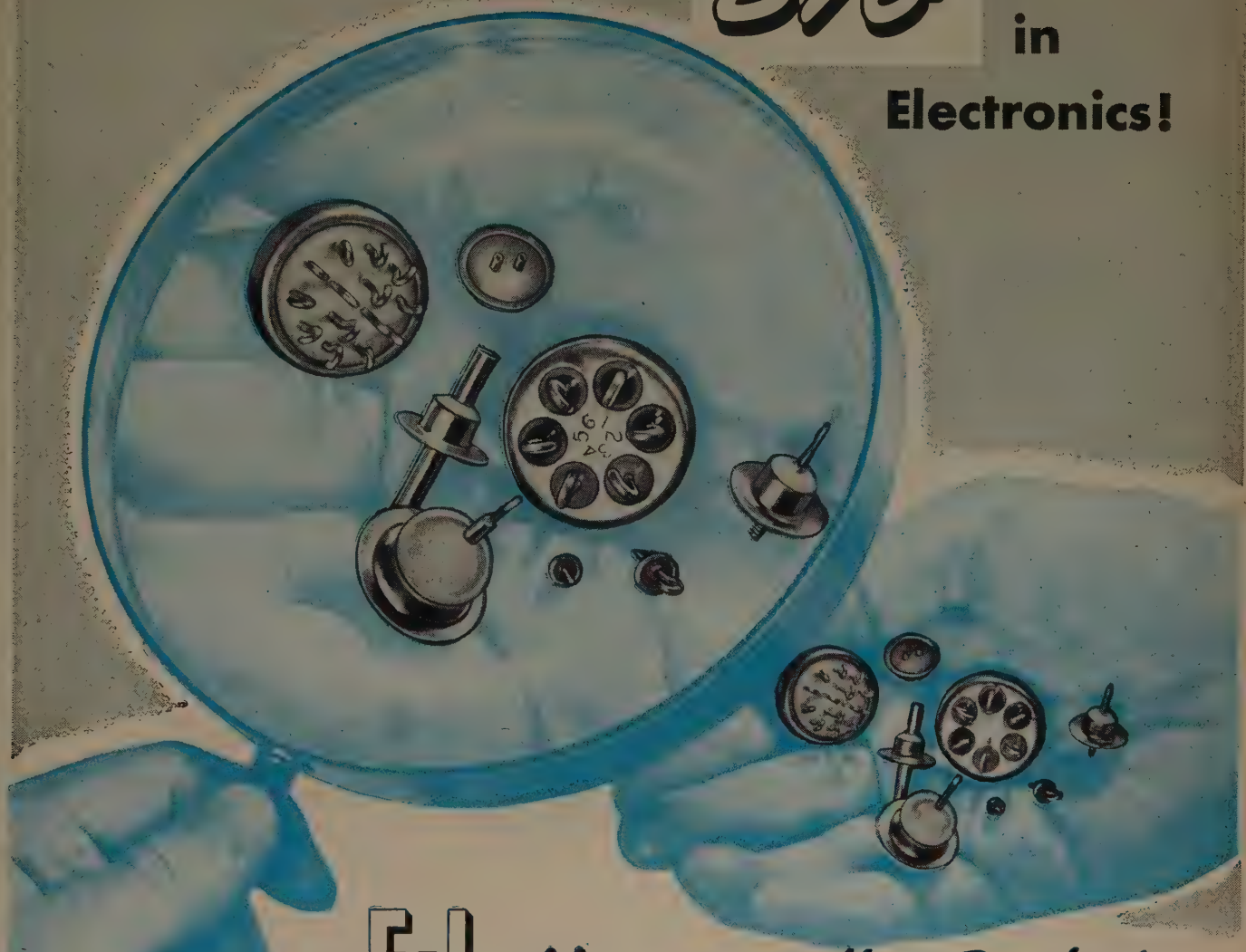
A minute after you've pulled the tab a finished print is ready for evaluation

FAIRCHILD

OSCILLOSCOPE RECORDING CAMERAS

SMALL PARTS

—figuring BIG in Electronics!



E-I *Hermetically Sealed* MULTIPLE HEADERS and SEALED LEADS

COMPLETELY ILLUSTRATED

LITERATURE AVAILABLE NOW!

Detailed data on standard designs is contained in new literature just off the press. Engineering assistance on special problems is also available without obligation. Please address requests on company letterhead

Hermetically sealed multiple headers and leads are vital parts of countless electronic and electrical assemblies. E-I offers these important components in over 100 different standard types with a variety of optional features. Thus, E-I offers a quick, economical solution to most terminal problems. **For specialized applications,** E-I engineers can design and produce multiple headers and sealed leads to meet your requirements at a practical cost. If your problem involves the hermetic sealing of terminals and leads, consult us today!

ELECTRICAL INDUSTRIES • INC.

44 SUMMER AVENUE, NEWARK 4, NEW JERSEY

MANUFACTURERS OF SPECIALIZED ELECTRONIC PRODUCTS AND EQUIPMENT

BUSINESS IN MOTION

To our Colleagues in American Business . . .

For several years this space has been used to tell how Revere has collaborated with its customers, to mutual benefit. Now we want to talk about the way our customers can help us, again to mutual benefit. The subject is scrap. This is so important that a goodly number of Revere men, salesmen and others, have been assigned to urge customers to ship back to our mills the scrap generated from our mill products, such as sheet and strip, rod and bar, tube, plate, and so on. Probably few people realize it, but the copper and brass industry obtains about 30% of its metal requirements from scrap. In these days when copper is in such short supply, the importance of adequate supplies of scrap is greater than ever. We need scrap, our industry needs scrap, our country needs it promptly.

Scrap comes from many different sources, and in varying amounts. A company making screw-machine products may find that the finished parts weigh only about 50% as much as the original bar or rod. The turnings are valuable, and should be sold back to the mill. Firms who stamp parts out of strip have been materially helped in many cases by the Revere Technical Advisory Service, which delights in working out specifications as to dimensions in order to minimize the weight of trimmings; nevertheless, such manufacturing operations inevitably produce scrap. Revere needs it. Only by obtaining scrap can Revere, along with the other companies in the copper and brass business, do the utmost possible in filling orders. You see, scrap helps us help you.

In seeking copper and brass scrap we cannot appeal to the general public, nor, for that matter, to the small businesses, important though they are, which have only a few hundred pounds or so to dispose of at a time. Scrap in small amounts is taken by dealers, who perform a valuable service in collecting and sorting it, and making it available in large quantities to the mills. Revere, which ships large tonnages of mill products to important manufacturers, seeks from them in return the scrap that is generated, which runs into big figures of segregated or classified scrap, ready to be melted down and processed so that more tons of finished mill products can be provided.

So Revere, in your own interest, urges you to give some extra thought to the matter of scrap. The more you can help us in this respect, the more we can help you. When a Revere salesman calls and inquires about scrap, may we ask you to give him your cooperation? In fact, we would like to say that it would be in your own interest to give special thought at this time to all kinds of scrap. No matter what materials you buy, the chances are that some portions of them, whether trimmings or rejects, do not find their way into your finished products. Let's all see that everything that can be re-used or re-processed is turned back quickly into the appropriate channels and thus returned to our national sources of supply, for the protection of us all.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

150th YEAR OF SERVICE TO AMERICA

Executive Offices:

230 Park Avenue, New York 17, N. Y.

SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

PRODUCTS OF WORLD-FAMOUS

DAVEN

CREATIVE-ENGINEERING

TYPE T-330

DAVEN ATTENUATORS

Exclusive Features:

1. "Knee-Action" Blade
   - Tamper proof
   - Uniform contact pressure and low contact resistance over the life of every unit.
   - Each rotor blade individually supported to give positive contact in operation under all types of conditions.
2. Brass Case of 2-Piece Construction
   - Greatly reduces clearance space required for removal of cover in rear of unit.
3. "Lock-Tite" Dust Cover
   - Held by positive, bayonet-type lock which prevents cover from falling off under stress of vibration.
4. Enclosed Roller-Type Detent Mechanism
   - For extra long life and positive indexing.
   - Addition of detent does not increase depth of unit.
5. Low-Loss Molded Terminal Board
   - For high resistance to leakage.
6. Rigidly Supported Resistor Strips
   - With air insulation.

YEARS AHEAD, CREATIVE-ENGINEERING

has always characterized Daven's efforts in the production of electronic components and equipment.

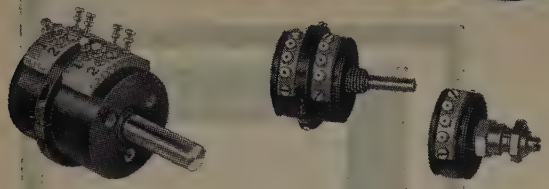
The unit illustrated above is only one in a complete line of Daven's world-famous attenuators. Because this Company has pioneered and created so many worth-while improvements in units of this type, you can do no better than to specify Daven Attenuators.

Daven's skilled staff of specialist-engineers is at your "beck and call" to help with your problems in the selection of the right attenuators for the equipment you are designing.

Write for complete catalog data.

THE DAVEN CO.
195 CENTRAL AVENUE
NEWARK 4, NEW JERSEY

There's a TIC® Potentiometer for every application



RVP3* High Precision machined aluminum base Potentiometers . . . available in models for either linear or non-linear functions with standard resistance values up to 200,000Ω. Linearity to ±0.1%. Eleven gang assembly shown — example of TIC's potentiometers multi-ganged with TIC's adjustable clamp ring. Can be supplied to meet various mounting requirements — single hole, 3 tapped hole mounting or servo mounting as desired.

Sine and cosine potentiometers available in RVP3* and RV2* bases.

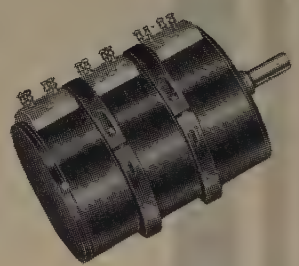
Miniaturization of precision potentiometers is keeping pace with the increased demand for smaller assemblies and compact design. Now you can minimize wasted space with TIC's outstanding, new RV⅞* and RVI-1/16* Miniature Potentiometers.

In spite of their thumbnail size the RV⅞ and the RVI-1/16 are precision, high linearity variable resistors, (or adjustable trimmers) of high stability — achieving a standard of performance hitherto unavailable in such miniature potentiometers.

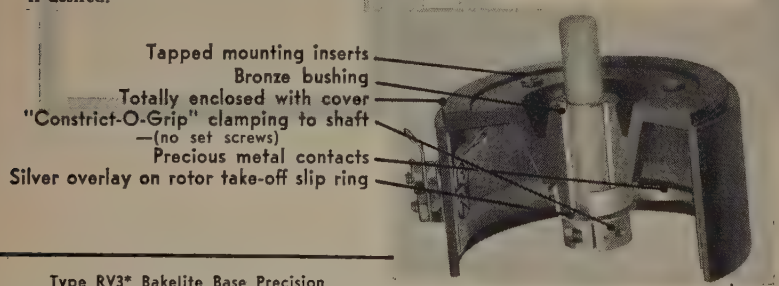
Construction features include: precision machined aluminum base . . . low torque . . . all soldered connections except sliding contacts . . . paliney contacts . . . can be sealed to withstand all humidity, salt spray and altitude specifications. Ganging if desired with TIC adjustable clamp ring.

RV⅞* available with linear resistance elements *only* — nine standard resistance values from 100 to 25,000 ohms. Power rating 6 watts at 25°C. Illustration shows RV⅞ with threaded bushing . . . servo mounting available if desired.

RVI-1/16* available with linear or non-linear resistance elements — nine standard resistance values from 100 to 50,000 ohms. Illustration shows RVI-1/16 with 3 tapped hole mounting . . . servo mounting or threaded bushing if desired.

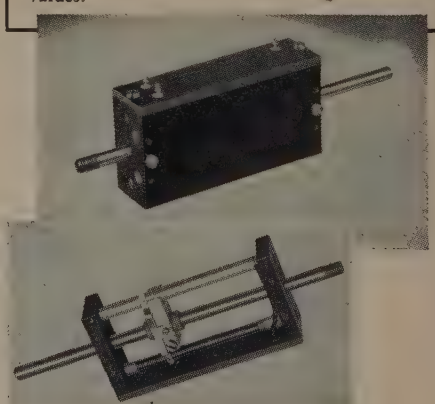


Type RV1⅝* and RV2* High Precision Potentiometers . . . semi-standardized types of precision machined aluminum base potentiometers with exceptionally high electrical accuracy and mechanical precision. For both linear and non-linear functions. Designed for precision instrument, computer and military applications. Accurate phasing of individual units possible with clamp-ring method of ganging. Ball bearing models available.



Type RVT Translatory Potentiometers . . . actuated by longitudinal instead of rotary motion providing linear electrical output proportional to shaft displacement. Used as a position indicator, high amplitude displacement type pickup and for studying low frequency motion or vibration. Features exceptionally high linearity and resolution. Available in various lengths and resistance values.

Type RV3* Bakelite Base Precision Potentiometers . . . available in models for either linear or non-linear functions. Stock resistance values ranging from 100Ω to 200,000Ω and power ratings of 8 and 12 watts. 360° mechanical rotation or limited by stops as desired. Potentiometers of this type available to widely varying accuracy requirements (linearity to ±0.25%) — see TIC Bulletin RV3-250. Special models available for high humidity applications.



Numbers refer to diameter of bases.

TECHNOLOGY INSTRUMENT CORP.

531 Main Street, Acton, Mass.

Telephone: Acton 600

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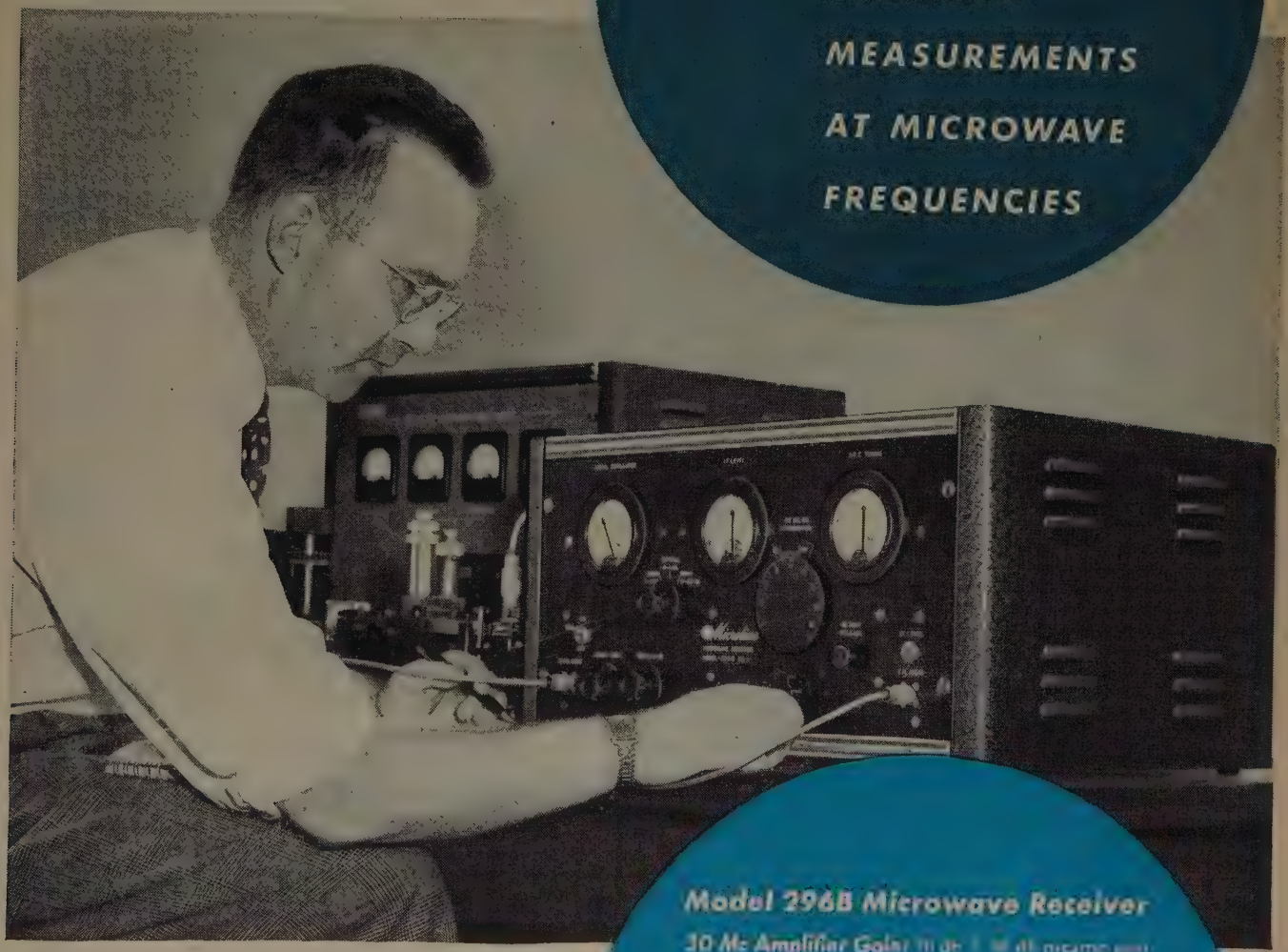
NEW SPERRY MICROLINE RECEIVER FOR ACCURATE MEASUREMENTS AT MICROWAVE FREQUENCIES

The newest addition to Sperry's Microline* is Model 296B Microwave Receiver for laboratory use. This instrument is an important addition to the microwave laboratory where a good secondary standard of attenuation is required.

The versatility of Model 296B permits measurements to be made at all microwave and UHF frequencies. In addition to its use as a secondary standard of attenuation, this receiver has many other uses . . . one of the more important being antenna pattern measurements.



Model 296B consists of a 30 mc pre-amplifier, IF amplifier and precision 30 mc waveguide below cut-off attenuator. Included in the receiver is a well-regulated klystron power supply. Klystron stability is assured by self-contained, automatic frequency control circuitry.

Our Special Electronics Department will be happy to give you further information on this instrument as well as other Microline equipment.

*T. M. REG. U. S. PAT. OFF.

Model 296B Microwave Receiver

30 Mc Amplifier Gain: [illegible]

IF Bandwidth: [illegible]

Attenuator: [illegible]

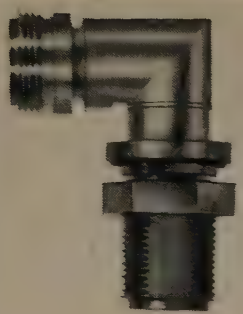
Local Oscillator Power Supply: [illegible]

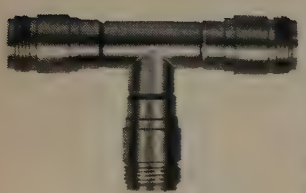
Accessories Supplied: [illegible]

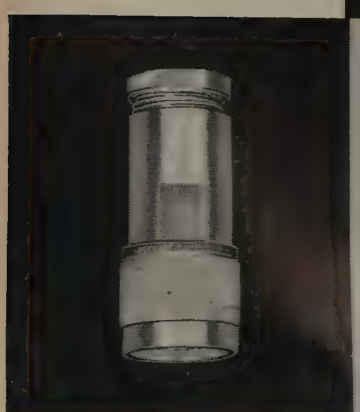
Accessories Needed: [illegible]

SPERRY GYROSCOPE COMPANY
DIVISION OF THE SPERRY CORPORATION

GREAT NECK, NEW YORK · CLEVELAND · NEW ORLEANS · BROOKLYN · LOS ANGELES · SAN FRANCISCO · SEATTLE
IN CANADA — SPERRY GYROSCOPE COMPANY OF CANADA, LIMITED, MONTREAL, QUEBEC







"N" SERIES R.F. CONNECTORS BY KINGS

Shown are a few of the "N" Series R.F. Connectors made by Kings. These low voltage connectors are of constant impedance and come in both weather-proof and non-weather-proof types.

Electronics engineers look to Kings for Connectors. A valued recognition which has been earned by many years of specialized work in this field. When you call on Kings you get the benefit of years of engineering, research and production experience and know-how.

You are invited to write for quotations and delivery dates on all standard and special connectors.

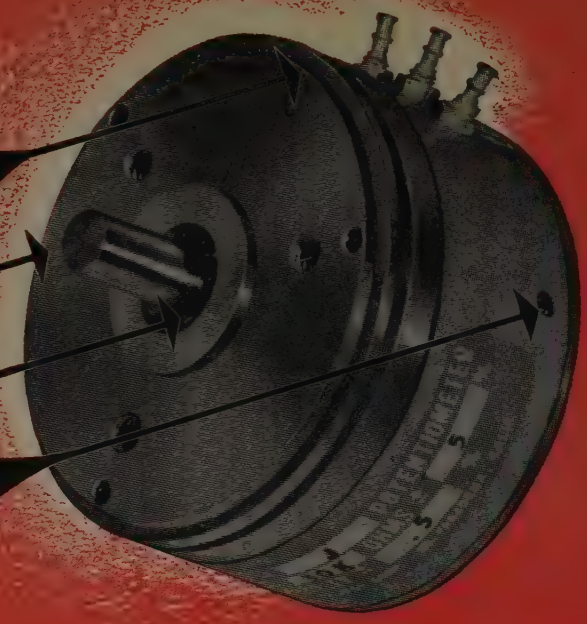
KINGS *Electronics* CO., INC.

40 MARBLEDALE ROAD, TUCKAHOE, N. Y.

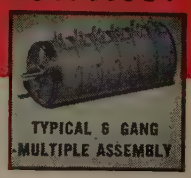
IN CANADA: ATLAS RADIO CORP., LTD., TORONTO

A New Concept in Precision Potentiometers . . .

THE MODEL J Helipot



. . . combined with mass-production economies!


TYPICAL 6 GANG MULTIPLE ASSEMBLY

***If it's a tough potentiometer problem, bring it to* Helipot**

—for Helipot has facilities and know-how unequalled in the industry for mass-producing precision potentiometers with advanced operating and electrical features.

This recently-developed 'Model J' Helipot, for example, combines several revolutionary advancements never before available in the potentiometer field . . .

Precise Mechanical Concentricity

Modern servo mechanisms and computer hook-ups require high mechanical precision to insure uniform accuracy when connected to servo motors through close-tolerance gears and couplings.

In the "Model J," close concentricity between mounting surface and shaft is assured by a unique mounting arrangement. The unit can be aligned on either of two wide-base flange registers and secured with three screws from the front of the panel . . . or it can be secured with adjustable clamps from the rear of the panel to permit angular phasing. Or if preferred, it can be equipped with the conventional single-hole bushing type of mounting.

In addition to accurate mounting alignment, exact rotational alignment is assured by the long-life, precision-type ball bearings upon which the shaft rotates. Precise initial alignment coupled with negligible wear mean high *sustained* accuracy.

High Electrical Accuracy

Helipot products have long been noted for their unusually high electrical accuracy and the "Model J" embodies the latest advancements of Helipot engineering in this field.

For example, tap connections are made by a new Helipot welding technique whereby the tap is connected to only ONE turn of the resistance winding. This unique process eliminates "shorted section" problems!

High linearity is also assured by Helipot's advanced production methods. Standard "Model J" linearity accuracies are guaranteed within ±0.5%. On special order, accuracies to ±0.15% (capacities of 5000 ohms and up) have been obtained.

Ball Bearing Construction

The shaft of each "Model J" is carefully mounted on precision-type ball bearings that not only assure sustained rotational accuracy, but also provide the constant low-torque operation so essential for servo and computer applications. Starting torque is only ¾ of an inch-ounce (±.25 in.-oz.)—running torque, of course, is even less.

Independent Phasing

When using the "Model J" in ganged multiple assemblies, each section can be independently phased electrically or mechanically—even after installation on the panel—by means of hidden internal clamps controlled from outside the housing. Phasing is simple, quick, accurate!

Mass-Production Economies

In addition to its many other unique features, Helipot engineers have developed unusual techniques that permit mass-production economies in manufacturing the "Model J". Actual price depends upon the number of taps required, special features, etc. . . . but with all its unique features, you will find the "Model J" very moderate in cost.*

Wide Choice of Designs

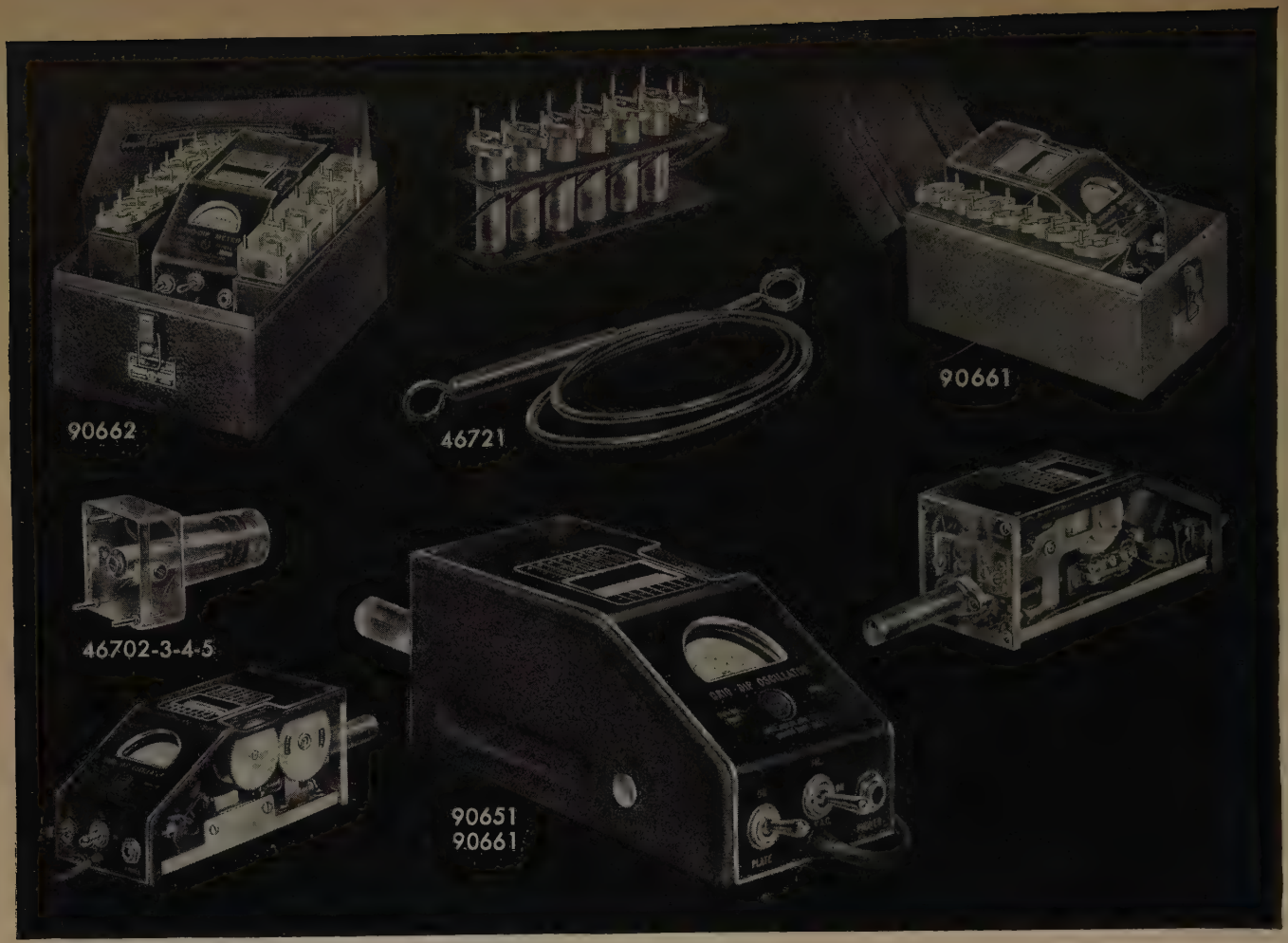
The "Model J" Helipot is available in a wide selection of standard resistance ranges—50, 100, 1,000, 5,000, 10,000, 20,000, 30,000 and 50,000 ohms . . . in single- or double-shaft designs . . . with choice of many special features to meet virtually any requirement within its operating field.

***Write for Bulletin 107 which gives complete data and price information on the versatile "Model J" Helipot!**

THE Helipot CORPORATION

South Pasadena 6, California

***Field Offices:* Boston, New York, Philadelphia, Rochester, Cleveland, Detroit, Chicago, St. Louis, Los Angeles and Fort Myers, Florida. *Export Agents:* Fratham Co., New York 18, New York.**



Designed for Application

Grid Dip Meters

Millen Grid Dip Meters are available to meet all various laboratory and servicing requirements.

The 90662 Industrial Grid Dip Meter completely calibrated for laboratory use with a range from 225 kc. to 300 mc. incorporates features desired for both industrial and laboratory application, including three wire grounding type power cord and suitable carrying case.

The 90661 Industrial Grid Dip Meter is similar to the 90662 except for a reduced range of 1.7 to 300 mc. It likewise incorporates the three wire grounding type cord and metal carrying case.

The 90651 Standard Grid Dip Meter is a somewhat less expensive version of the grid dip meter. The calibration while adequate for general usage is not as complete as in the case of the industrial model. It is supplied without grounding lead and without carrying case. The range is 1.7 to 300 mc. Extra inductors available extends range to 220 kc.

The Millen Grid Dip Meter is a calibrated stable RF oscillator unit with a meter to read grid current. The frequency determining coil is plugged into the unit so that it may be used as a probe.

These instruments are complete with a built-in transformer type A.C. power supply and interminal terminal board to provide connections for battery operation where it is desirable to use the unit on antenna measurements and other usages where A.C. power is not available. Compactness has been achieved without loss of performance or convenience of usage. The incorporation of the power supply, oscillator and probe into a single unit provides a convenient device for checking all types of circuits. The indicating instrument is a standard 2 inch General Electric instrument with an easy to read scale. The calibrated dial is a large 270° drum dial which provides seven direct reading scales, plus an additional universal scale, all with the same length and readability. Each range has its individual plug-in probe completely enclosed in a contour fitting polystyrene case for assurance of permanence of calibration as well as to prevent any possibility of mechanical damage or of unintentional contact with the components of the circuit being tested.

The Grid Dip Meters may be used as:

1. A Grid Dip Oscillator
2. An Oscillating Detector
3. A Signal Generator
4. An Indicating Absorption Wavemeter

The most common usage of the Grid Dip Meter is as an oscillating frequency meter to determine the resonant frequencies of de-energized tuned circuits.

Size of Grid Dip Meter only (less probe): 7 in. x 3⅛ in. x 3⅜ in.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY

MALDEN, MASSACHUSETTS, U.S.A.

"Eimac 4-65A fits exacting requirements"

John M. Kaar, President of Kaar Engineering Co., prominent manufacturers of high quality radio-telephone equipment.

KAAR ENGINEERING CO.
Largest West Coast Manufacturer of Radiotelephone Equipment

PHONE DAVENPORT 3-9001
2995 MIDDLEFIELD ROAD
PALO ALTO, CALIFORNIA

July 13, 1951

Eitel-McCullough, Inc.
798 San Mateo Avenue
San Bruno, California

Gentlemen:

For some time now our FM-179X 50 Watt mobile transmitters have been in use, many of them in foreign countries under extremely trying operating conditions.

We believe you would be interested in knowing that the Eimac 4-65A was the only tube that could fit our exacting requirements in designing this equipment. The 4-65A combines ruggedness, dependability and high power output in an instant-heating tube that can stand up under the most difficult operating conditions. It made possible the design of a compact high-powered mobile transmitter with extremely low vehicle battery drain.

Cordially,

John M. Kaar

John M. Kaar

INSTANT HEATING

Eimac 4-65A tetrodes are the heart of the Kaar FM-179X mobile transmitter. As Mr. Kaar indicates, his engineers chose these tetrodes because they were known to be outstandingly dependable and because they exhibit highly desirable operating characteristics.

The 4-65A is excellent for power amplifier and modulator service in both fixed and mobile stations. They operate over a plate voltage range from 600 to 3000 volts with output powers ranging from 50 to 280 watts per tube. Upper operating frequency of the 4-65A under normal conditions is 220 Mc.

Put Eimac 4-65A tetrodes to work for you . . . take advantage of their proved performance and low cost. Complete data available upon request.

Follow the Leaders to Eimac TUBES The Power for R-F

301

EITEL-McCULLOUGH, INC.
San Bruno, California
Export Agents: Frazar & Hansen, 301 Clay St., San Francisco, California

175 SERIES
125 SERIES
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90 SERIES
5 BASIC SIZES
70 SERIES
STANDARD CONTROL KNOBS by RAYTHEON®
Excellence in Electronics
Now, for the first time . . . standard control knobs worthy of the finest commercial or military equipment . . . available in a complete choice of widely used sizes and functional styles —*without the heavy expense of custom designing and tooling.*
Made of tough, durable "Tenite II" (cellulose acetate butyrate) with dual setscrews and anodized aluminum inserts drilled for ¼-inch diameter shafts. Miniature (70 Series) round, dial and pointer knobs also available for ⅛-inch shafts.
Black knobs can be furnished with high gloss *mirror finish* for commercial applications or with non-reflecting *matte finish* for use on government equipment. Manufacturers interested in colored knobs to match, blend, or contrast with color styled equipment are invited to submit their requirements for quotation.
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DIAL SKIRTED ROUND
CRANK

Don't be "blinded" to your future!

THE COURSE OF YOUR CAREER may depend upon what you do about your future—now. A sure way to miss success is to miss opportunity.

Now is the time for qualified ELECTRONIC, ELECTRICAL and MECHANICAL ENGINEERS . . . PHYSICISTS . . . METALLURGISTS . . . CHEMICAL and CERAMIC ENGINEERS . . . as well as TECHNICAL SALES ENGINEERS to decide to take full advantage of the opportunities now open at RCA to achieve professional success.

LIFELONG CAREER OPPORTUNITIES

These are not temporary positions. They are independent of national defense requirements. The openings represent a wide choice of long-term government projects as well as challenging work in the permanent expansion of a diversified line of commercial products.

YOU ENJOY THESE BENEFITS

At RCA, you enjoy professional status, recognition for accomplishments . . . unexcelled research facilities for creative work . . . opportunities for advancement in position and income . . . pleasant surroundings in which to work. You and your families participate in Company-paid hospital, surgical, accident, sickness and life insurance. Modern retirement program. Good suburban or country residential and recreational conditions. Opportunities for graduate study. Investigate opportunities today.

POSITIONS OPEN IN THE FOLLOWING FIELDS:

TELEVISION DEVELOPMENT—
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ELECTRON TUBE DEVELOPMENT—
Receiving, Transmitting, Cathode-Ray, Phototubes and Magnetrons

TRANSFORMER and COIL DESIGN

COMMUNICATIONS—
Microwave, Mobile, Aviation, Specialized Military Systems

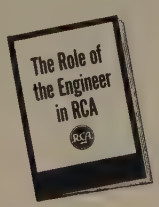
RADAR—
Circuitry, Antenna Design, Computer, Servo-Systems, Information Display Systems

INDUSTRIAL ELECTRONICS—
Precision Instruments, Digital Circuitry, Magnetic Recording, Industrial Television, Color Measurements

NAVIGATIONAL AIDS

TECHNICAL SALES

ELECTRONIC EQUIPMENT FIELD SERVICE



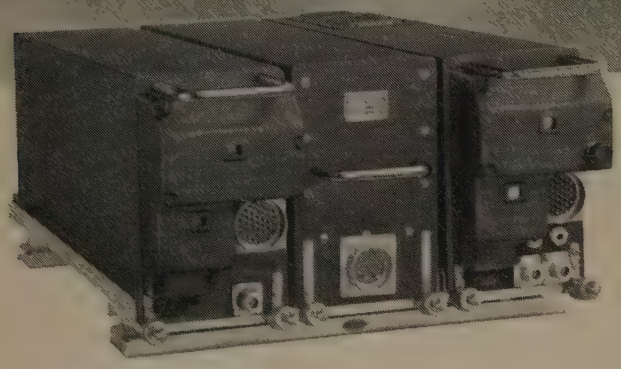
Whatever your plans for the future—you will find the booklet "The Role of the Engineer in RCA" interesting reading. Write for your *free* copy.

MAIL RESUMÉ

If you qualify for any of the positions listed above, send us a complete resumé of your education and experience, also state your specialized field preference. Send resumé to:

MR. ROBERT E. McQUISTON,
Specialized Employment Division, Dept. 94X
Radio Corporation of America,
30 Rockefeller Plaza,
New York 20, N. Y.

RCA RADIO CORPORATION of AMERICA



WILCOX ...Choice of EASTERN Air Lines

180 Channel WILCOX Communications System Chosen for Eastern's Entire Fleet of SUPER CONSTELLATIONS and MARTIN 4-0-4's

Eastern Air Lines demanded the finest communications equipment available to match the advanced, efficient operation of their modern new fleet. No greater compliment could be paid to Wilcox radio equipment than to be selected for this challenging assignment.

The Wilcox 440A VHF Communications System covers all channels in the 118-136 Mc. band. It is light in weight, small in size, and easy to maintain.

UNIT CONSTRUCTION FOR EASY HANDLING

The 50-watt transmitter, high sensitivity receiver, and compact power supply are each contained in a separate JAN A1-D case. Any unit may be instantly removed from the common mount.

FINGER-TIP REMOTE CONTROL

All transmitter and receiver functions are available by remote control. A new channel selector system assures positive operation and minimum maintenance.

DEPENDABILITY AND EASY MAINTENANCE

Simple, conventional circuits minimize the number and types of tubes and require no special training, techniques, or test equipment.

Write Today FOR COMPLETE INFORMATION ON THE WILCOX 440A 180 CHANNEL VHF COMMUNICATIONS SYSTEM

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PERMENDUR*

gives you

- ☆ High Magnetic Saturation
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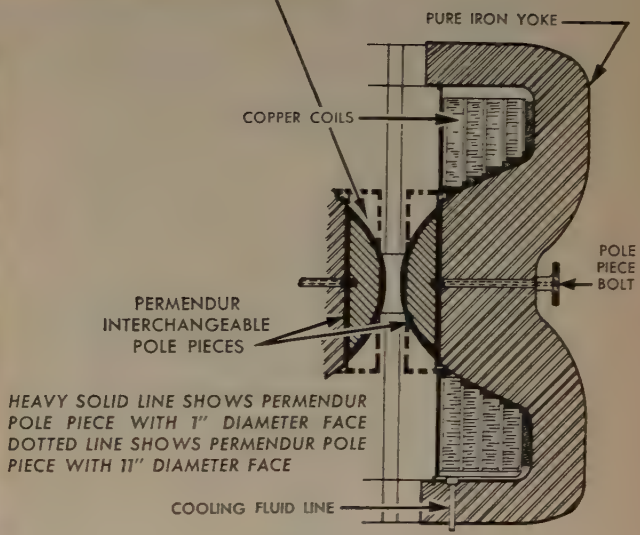
- ☆ Design Possibilities for Savings in Weight, Space and Materials

Typical use of Permendur in the ADL ELECTROMAGNET

(ARTHUR D. LITTLE, Inc.)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HEAVY SOLID LINE SHOWS PERMENDUR POLE PIECE WITH 1" DIAMETER FACE
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Sectional Detail of Yoke Half

Permendur is available in Forgings, Castings, Hot-Rolled Bars and Plates to meet your design needs for form or shape. *Write for information*

*Manufactured under license arrangements with Western Electric Co.

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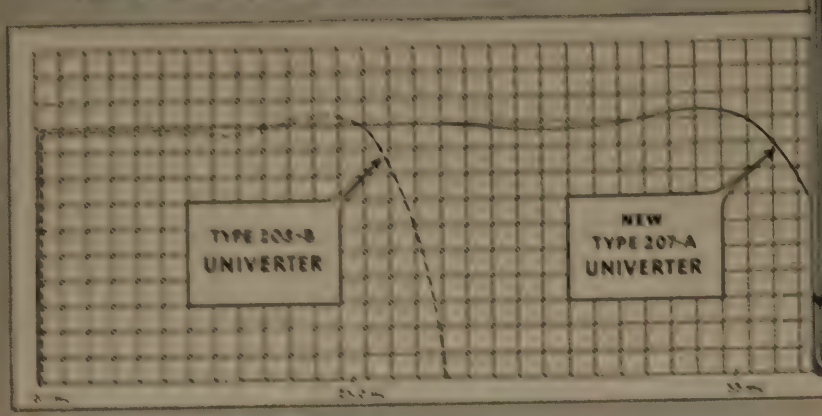
General Office & Plant: Marengo, Illinois

Wide Band UNIVERTER

for complete frequency coverage

when used with the

FM-AM SIGNAL GENERATOR TYPE 202-B



FM-AM SIGNAL GENERATOR

TYPE 202-B

- *The standard signal source for the FM and TV industry.*
- *Univerter 207-A extends frequency range down to 0.1 mc. without change in signal level or modulation characteristics below.*

SPECIFICATIONS:

RF RANGES: 54-108, 108-216 mc.
FREQUENCY DEVIATION: 0-24 kc., 0-80 kc., 0-240 kc.
FM DISTORTION: Less than 2% at 75 kc. deviation
AMPLITUDE MODULATION: Continuously variable 0-50%.
RF OUTPUT VOLTAGE: 0.1 microvolt to 0.2 volt.

PRICE $975.00 F. O. B. BOONTON, N. J.

UNIVERTER

TYPE 207-A

The Univerter Type 207-A provides a continuous extention of the frequency range of the 202-B FM-AM Signal Generator down to 0.1 mc. The two instruments may be used over a continuous frequency range of 0.1 mc. to 216 mc. The Univerter Type 207-A subtracts 150 mc. from a signal obtained from the 202-B and provides outputs between 0.1 mc. and 55 mc. without change of signal level. Negligible spurious signals are introduced and modulation of the signal is unaffected. Small incremental changes can be made in frequency to allow the study of band pass characteristics of very narrow band receivers. A regulated power supply prevents change of gain or frequency with line voltage.

SPECIFICATIONS (*When used with 202-B*)

FREQUENCY RANGE: 0.1 mc. to 55 mc. (0.3 mc. to 55 mc. with 200 kc. carrier deviation).

FREQUENCY INCREMENT DIAL: Plus or minus 300 kc. calibrated in 5 kc. increments.

FREQUENCY RESPONSE: Flat within ±1 db over frequency range.

FREQUENCY ADJUST: Front panel control allows calibration with 202-B output.

OUTPUT: Continuously variable, at XI jack from 0.1 microvolt to 0.1 volt across 53 ohms by use of 202-B attenuator.

HIGH OUTPUT: Uncalibrated approximately 1.5 volts from 250 ohms into open circuit.

DISTORTION: No appreciable FM distortion at any level.
No appreciable AM distortion at carrier levels below 0.05 volt and modulation of 50%.

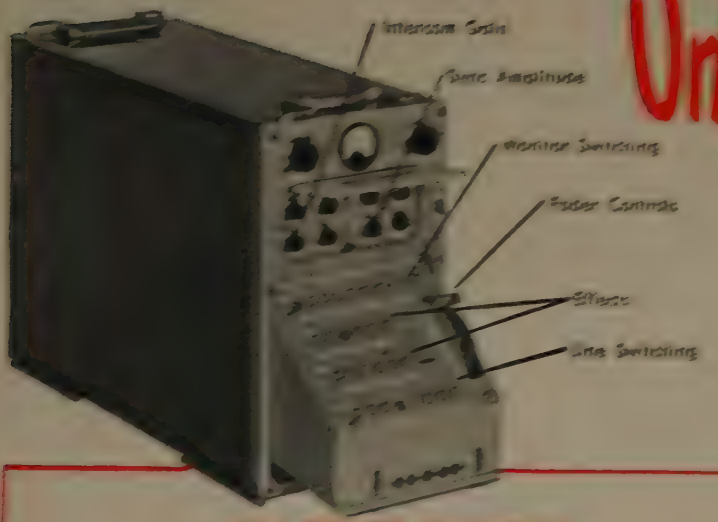
SPURIOUS RF OUTPUT: At least 30 db down at input levels less than 0.05 volts.

PRICE $345.00 F. O. B. BOONTON, N. J.

BOONTON RADIO *Corporation*
BOONTON, N. J.

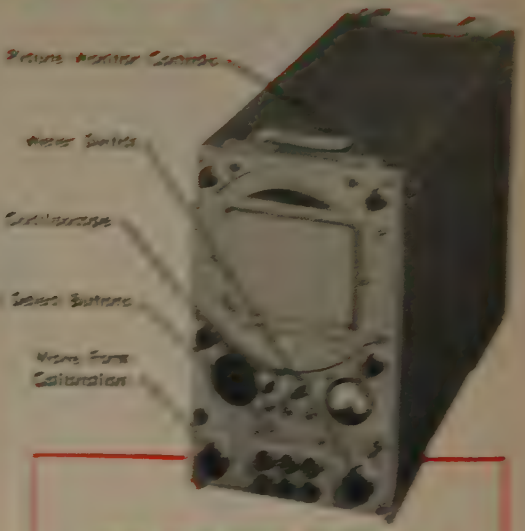
TWO CHAMPIONS

THAT MAKE AN Unbeatable Team!



GPL VIDEO SWITCHER

- Studio switching flexibility anywhere
- Panel and active buttons internally illuminated
- Portable, self-contained — Panel enclosed for transit
- Monitor views 5 camera inputs, 2 remotes, outgoing line
- Sound interlock switching for remotes and 2 cameras
- Two open panel positions, 90° and 120°
- Switch panel removable, operative to 5 feet
- Twin fading levers for fades, dissolves
- Two "effects" buses
- Styled to match all GPL TV equipment



GPL MASTER MONITOR

- Selection of 5 pre-set inputs
- 5" Monitoring tube
- 2" Oscilloscope, also providing test facilities
- Meter readings of line voltage and power supply outputs
- Test sweep for observing vertical sync black
- Black-reference calibration voltage button
- Automatic sync of oscilloscope and waveform sweeps at half-line or half-field frequency
- Regulated pulse high voltage supply isolated from sweep circuits
- High impedance bridging input
- Compact, portable
- Ready accessibility of all controls, tubes, circuits

For the new station, for the expanding station, GPL's champion team of Video Switcher and Master Monitor affords a new high in quality, in field flexibility, in rehearsal and programming control. Both units are packaged for easy portability, with self-contained power supplies. Either can be integrated into your present installation to accommodate your particular operating conditions.

The Switcher and Monitor team is another example of GPL unique achievement in the production of high quality, high utility equipment for TV stations — another reason why GPL is THE INDUSTRY'S LEADING LINE — IN QUALITY, IN DESIGN.

WRITE, WIRE or PHONE FOR DETAILS TODAY

GENERAL PRECISION LABORATORY INCORPORATED

Pleasantville New York

TV Camera Chains • TV Film Chains
TV Field and Studio Equipment
Theatre TV Equipment

These are
Tantalytic Capacitors
12 Muf 150 VDC
8 Muf 150 VDC
2 Muf 150 V NP
1 Muf 150 V NP
4 Muf 60 VDC
.50 Muf 150 V NP
.25 Muf 150 V NP
.1 Muf 150 V NP
.04 Muf 150 V NP

Here is one of the fastest moving developments in recent years—General Electric's new electrolytic-type capacitors. These Tantalytic capacitors with their small size and large capacitance per unit of volume have excellent low temperature characteristics, long operating life and in many cases can replace bulky hermetically-sealed paper capacitors. Ratings presently available for consideration range from .02 muf up to 12 muf at 150 volts dc. Units pictured are representative of these ratings.

Other features of G-E Tantalytic Capacitors include:

- Extremely long shelf life.
- An operating temperature range from −55°C to +85°C.
- Exceedingly low leakage currents.
- Ability to withstand severe physical shock.
- Completely sealed against contamination.

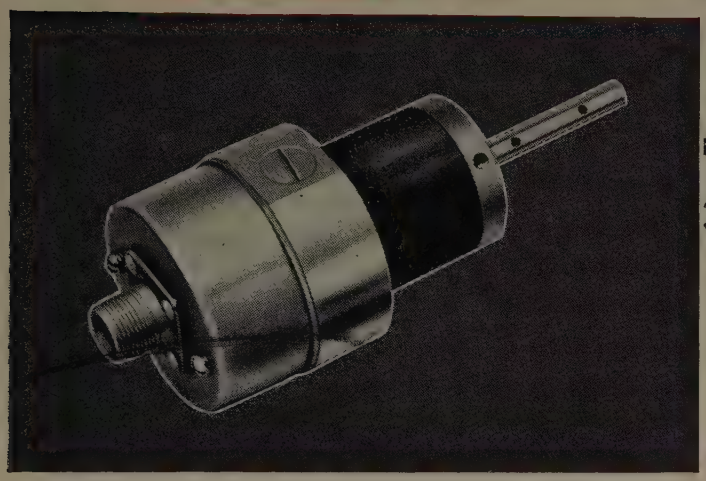
If you have large-volume applications where a price of 3 to 5 times that of hermetically-sealed paper capacitors is secondary to a combination of small size and superior performance—get in touch with us. Your letter, addressed to Capacitor Sales Division, General Electric Company, Hudson Falls, N. Y., or your nearest Apparatus Sales Office will receive prompt attention.

General Electric Company, Schenectady 5, N. Y.

GENERAL ELECTRIC

407-306

Let Bendix Solve Your Problems



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AND

DC MOTORS

When you are faced with specifications that place impossible requirements on dynamotors or small DC motors, according to World War II standards, take advantage of recently developed improvements in high temperature and high altitude techniques by simply outlining your requirements to Bendix. Model units *exactly* meeting your performance specifications will be developed and tested for pre-production use—production units will then follow in accordance with your manufacturing schedule.

DYNAMOTORS
Regular • Multiple output • Special purpose

DC MOTORS
1/100 hp—1/2 hp • Continuous and Intermittent Duty
DC Servos and special motors

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Write for this colorful and informative book —it's free. You'll find it loaded with facts and figures about all types of dynamotors.

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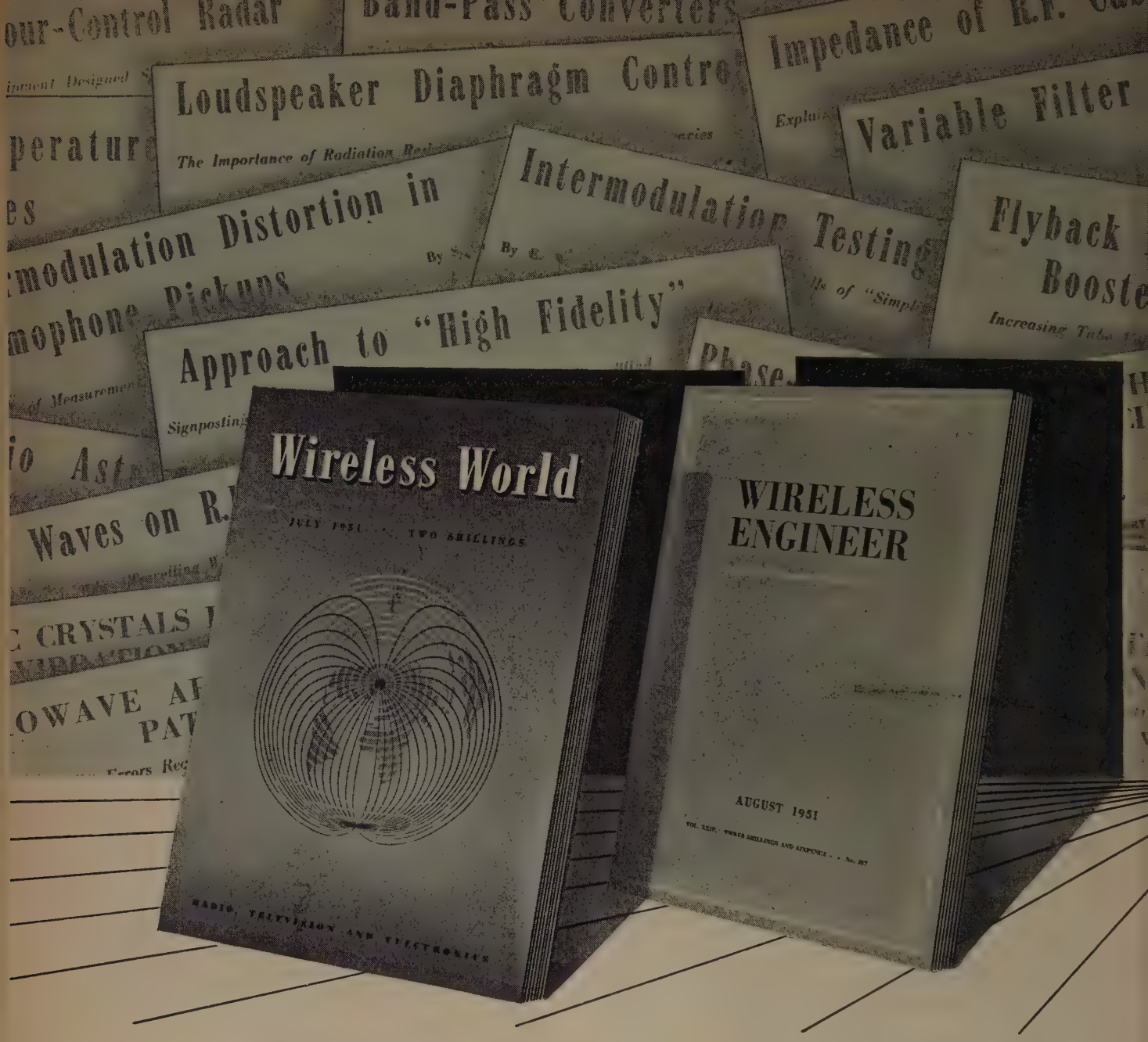

Up-to-date news of every British development

WIRELESS WORLD. Britain's leading technical magazine in the general field of radio, television and electronics. Founded over 40 years ago, it provides a complete and accurate survey of the newest British technique in design and manufacture. Critical reviews of the latest equipment, broadcast receivers and components of all types are regularly included. Theoretical articles deal with design data and circuits for every application and news from all parts of the world is reported. Monthly, 2s. Annual Subscription - - £1 7s. ($4.50).

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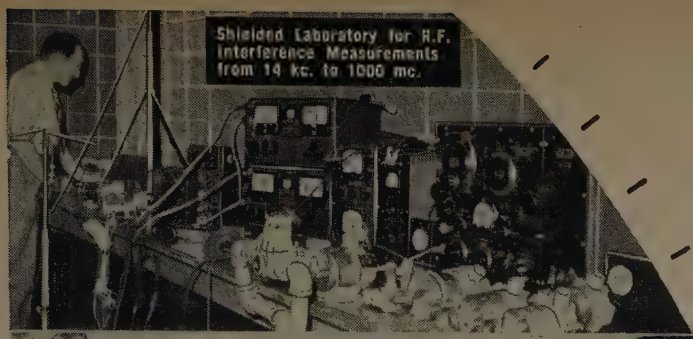

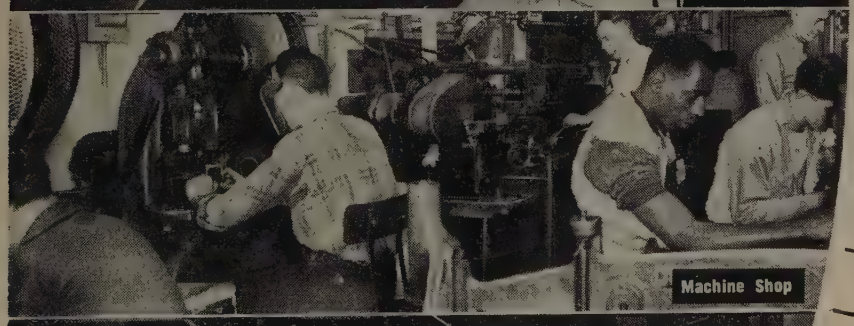

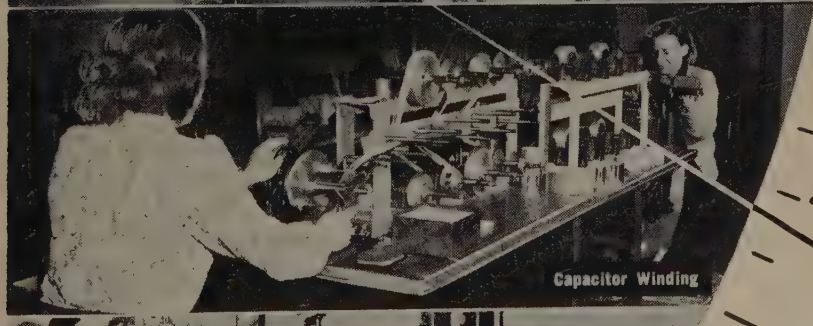

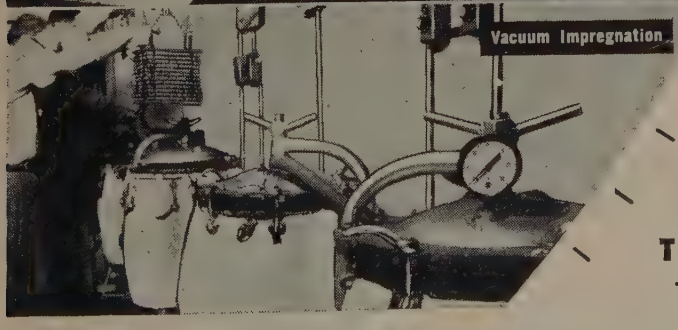

FILTRON'S *Ahead*

in

- **QUALITY**
- **PRODUCTION**
- **ENGINEERING**

FILTRON'S COMPLETE FACILITIES: capacitor manufacturing, coil winding, stamping department, tool and die shop, and assembly department, together with its Engineering and Research laboratories insures quality production and ON SCHEDULE DELIVERY.

FILTRON'S *advanced* engineering, due to constant research and development by engineers with years of R.F. INTERFERENCE experience has resulted in *smaller, lighter,* and more *efficient* R.F. Interference Filters.

FILTRON'S completely equipped shielded laboratory is available for the R.F. Interference testing and filter design for your equipment *...to specification requirements.*

With over *400 standard filters* to choose from, and the engineering know-how to custom design filters to meet specific size and mounting requirements, Filtron's engineers will specify the *right filter* for your application.

FILTRONS are suppressing R.F. Interference in modern Military Aircraft, Naval Equipment and Ground Signal Installations.

FILTERED BY FILTRON means...
RADIO INTERFERENCE FREE PERFORMANCE.

RF INTERFERENCE FILTERS FOR:

Electronic Controls	Signal Systems
Electric Motors	Business Machines
Electric Generators	Electric Appliances
Electronic Equipment	Electronic Signs
Fluorescent Lights	Electronic Heating
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LARGEST EXCLUSIVE MANUFACTURERS OF RF INTERFERENCE FILTERS

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- Television
- Video and display systems
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In each of the defense-important fields listed here, the Gray organization has recently solved important problems. These facilities are available to prime contractors and to the military services as our contribution to the national effort in furtherance of communications, engineering or electro-mechanical designing. A booklet telling more of the Gray story will be sent for the asking.

● Please write for Bulletin RE-12 describing the above equipment

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Division of The GRAY MANUFACTURING COMPANY—
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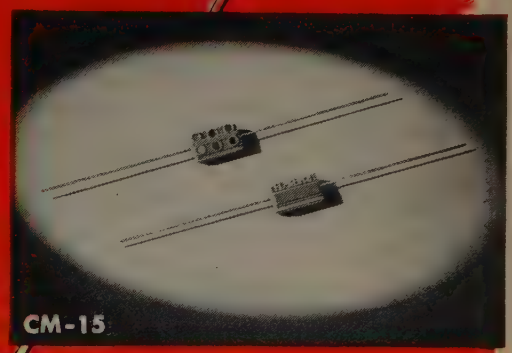
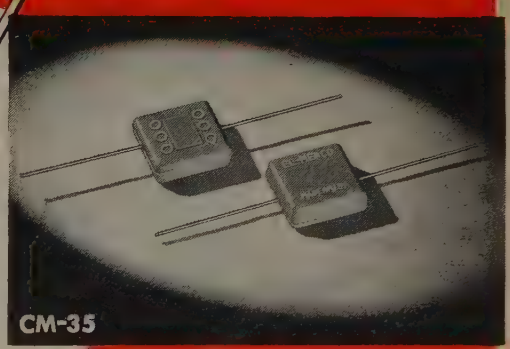
From the midget champ which spins around a ¼ mile oval in 19 seconds . . . to the Indianapolis winner which clocks 157 m.p.h. on the straightaway . . . performance is the key note in auto racing. In Electronics El-Menco Silvered-Mica Capacitors set the space. From the tiny CM-15 (2-525 mmf. cap.) to the mighty CM-35 (3300-10000 mmf. cap.) . . . unexcelled performance is paramount.

Precision workmanship, fine materials, careful design . . . these are the qualities which produce peak performance in racing cars and in El-Menco Capacitors. There is an El-Menco Capacitor for every specified military capacity and voltage. Each unit is factory-tested at *double* its working voltage. You are assured of dependability for every application.

For higher capacity values — which require extreme temperature and time stabilization — there are no substitutes for El-Menco Silvered-Mica Capacitors.


CM-15


CM-35

***Jobbers, Retailers, Distributors*—For information communicate direct with Arco Electronics, Inc., 103 Lafayette St., New York, N. Y.**

Write on your business letterhead for catalog and samples.

MOLDED MICA El-Menco MICA TRIMMER CAPACITORS

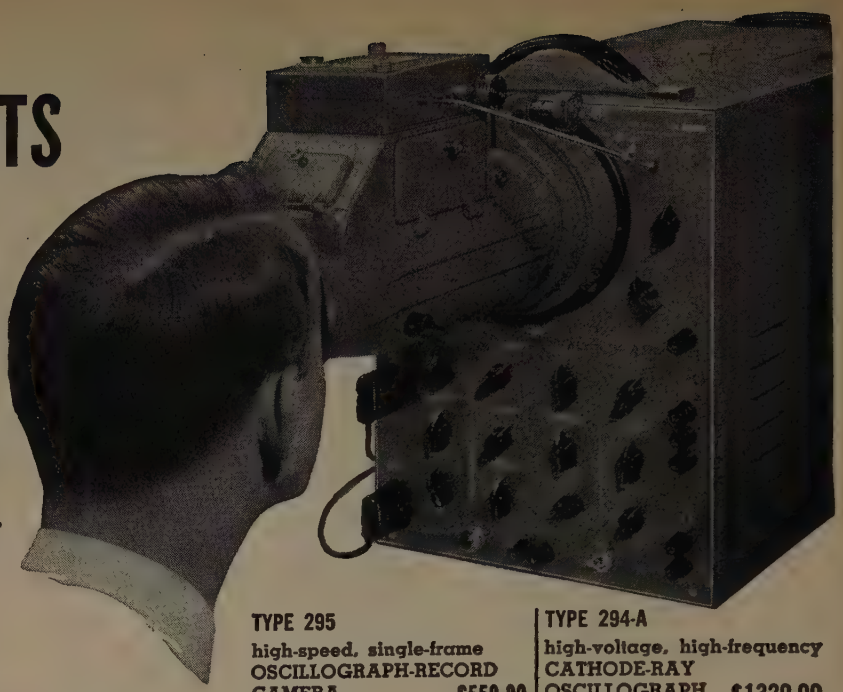
Radio and Television Manufacturers, Domestic and Foreign, Communicate Direct With Factory—

THE ELECTRO MOTIVE MFG. CO., INC. **WILLIMANTIC, CONNECTICUT**

A COMPLETE APPROACH TO

SINGLE TRANSIENTS and PULSES of low-repetition rate

For visual observation of pulses and single transients, the Type 294-A Cathode-ray Oscillograph provides high light-output and wide-band response. For careful study and permanent reference of these signals the Type 295 Oscillograph-record Camera records writing rates as high as 35 inches per microsecond.

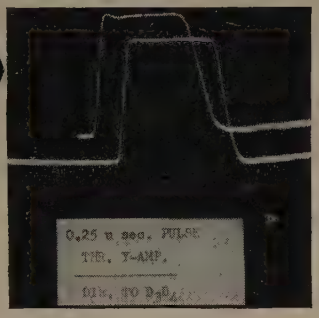


TYPE 295
high-speed, single-frame
OSCILLOGRAPH-RECORD
CAMERA **$550.00**

TYPE 294-A
high-voltage, high-frequency
CATHODE-RAY
OSCILLOGRAPH **$1320.00**

PULSE RESPONSE FREQUENCY RESPONSE SENSITIVITY

This oscillogram illustrates the double exposure technique. Binocular viewing in the Type 295 facilitates proper positioning for close comparison.



The pulses in the oscillogram at left are identical pulses of 0.25 microsecond width. The first pulse was applied through the Y-axis amplifier of the Type 294-A, and the second, directly to the vertical deflection plates. A comparison of their waveforms illustrates the excellent transient response of the Y-axis of the Type 294-A.

Response of the Y-axis amplifier to a rise time of 0.01 microsecond or less is 0.03 microseconds max. Notice that a minimum of overshoot (less than 2%) is introduced by the amplifier.

For the study of sinusoidal frequencies, the response of the Type 294-A extends from 10 cps. to 12 megacycles (down 30%). Sensitivity of the Y-axis, through the amplifier, is 0.42 peak-to-peak volts per inch.

AVAILABLE DEFLECTION LIGHT OUTPUT SIGNAL DELAY

"Time" and "Bulb" exposures may be taken with the Type 295. And provision is made so that equipment may be triggered simultaneously with shutter opening. With appropriate accelerating potentials, the Type 295 is capable of recording single transients in excess of 280 inches per microsecond.

The Type 294-A provides undistorted vertical deflection of 1.3 inches or more for both positive and negative pulses; and 2.75 inches for symmetrical signals. The high light-output of the Type 294-A increases the value of the large, vertical deflection provided by the Y-axis amplifier. This is illustrated by the high visibility of the rise and decay of the pulse shown at left. Here, the Type 5XP— Cathode-ray Tube of the Type 294-A was operated at 12 kv. However, where maximum light output is not required, the accelerating potential may be lowered to 7 kv by means of a switch. At this level of operation, of course, the available undistorted deflection is increased.

To insure the complete display of fast pulses such as those at left, the Y-axis includes a 0.25 microsecond signal-delay line.

SWEEP SPEEDS TIME CALIBRATION

The built-in illuminated datacard of the Type 295 will prove invaluable when making time measurements. A film take-up cassette is arranged so that exposed frames of film may be separated from unexposed film and taken to the darkroom for immediate developing.

Complementing the Y-axis performance of the Type 294-A, sweep durations are continuously variable from 0.1 second to 3 microseconds. By increasing the length of the sweep, speeds greater than 0.25 microsecond per inch may be obtained, thus providing more detail to facilitate the study of short-duration pulses.

Calibration of the sweeps of the Type 294-A is accomplished with vertical marks occurring at intervals of 100, 10, 1, or 0.1 microseconds. In the oscillogram at left, the 0.1 microsecond markers appear mixed with the signal on the vertical axis. Time measurements may also be made by double exposure of first, the signal, and second, the timing markers.

Send requests for information to

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for Oscillography

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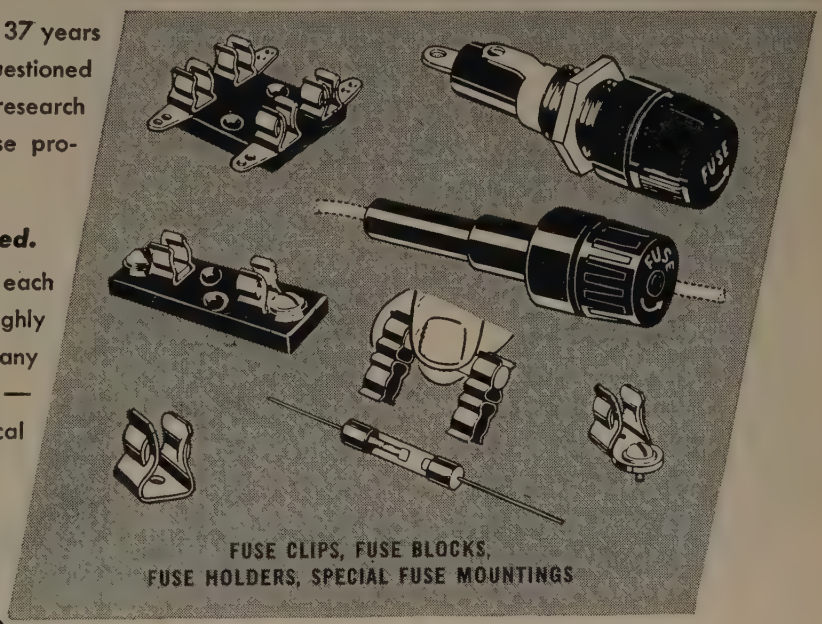

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FUSE HOLDERS, SPECIAL FUSE MOUNTINGS

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We welcome requests to help you in selecting the proper fuse or in designing a special fuse or fuse mounting best suited to your conditions. Submit sketch or description showing type of fuse contemplated, number of circuits, type of terminals and the like.

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Truscon *micro-precision* typified in this new microwave tower

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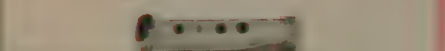
Compare for size with other Ceramic Capacitors, and specify ERIE GP3 Miniature Ceramicons for Space Saving By-Pass and Coupling Applications.

GP3 Ceramicons are manufactured with the use of a high dielectric constant ceramic developed especially for these compact tubular capacitors. Basic development work has been accomplished over the past few years in Erie's engineering laboratories. Since 1945 these units have been made on special order, and they are now available in production quantities

Write for complete information and samples

GP3 STYLE	MAXIMUM CAPACITANCE
STYLE 301 .200 x .400	.001 mfd.
STYLE 302 .200 x .650	.015 mfd.
 STYLE 307 .200 x .800	.0075 mfd.

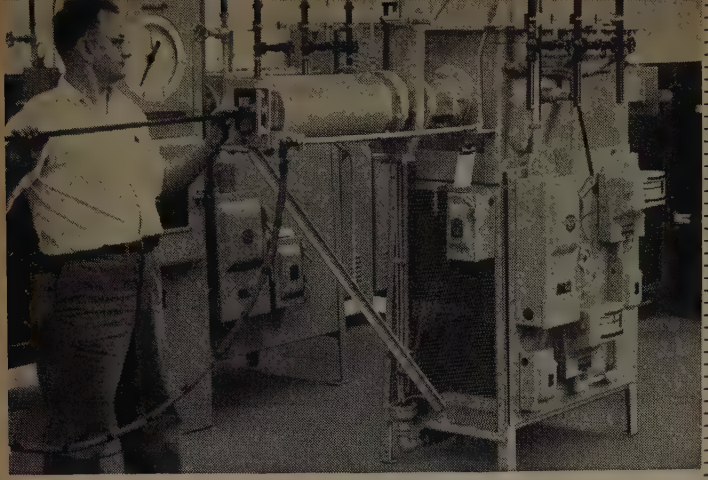
Tolerance on Capacitance: —20%, —20%, +80% or Test 1500 VDC

Life Test 750 VDC 1000 hours at 85° C

Electronics Division
ERIE RESISTOR CORP., ERIE, PA.
LONDON, ENGLAND · TORONTO, CANADA

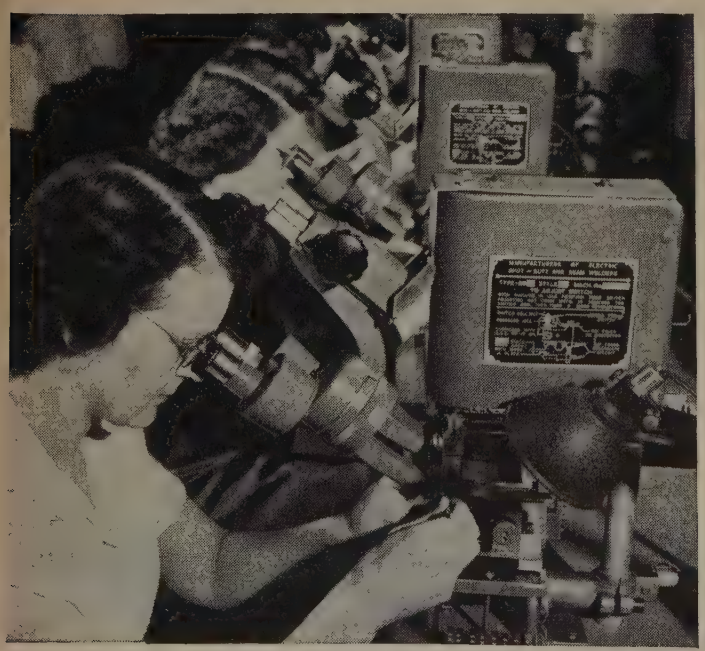
NEW GENERAL ELECTRIC PLANT PRODUCES RECORD VOLUME OF

WELDED GERMANIUM DIODES



1. MAXIMUM METAL PURITY is essential in the manufacture of diodes. In photograph above dioxide powder is being reduced to pure germanium metal.

2. GERMANIUM PELLETS are mounted to pin assemblies prior to assembly in cases. Precision centering as well as speed are essential to produce these quality units at low cost.



3. FORMING, SHEARING, AND WELDING WHISKERS on diode pin assembly calls for careful manipulation under microscope for accurately formed .003 inch diam. whisker.

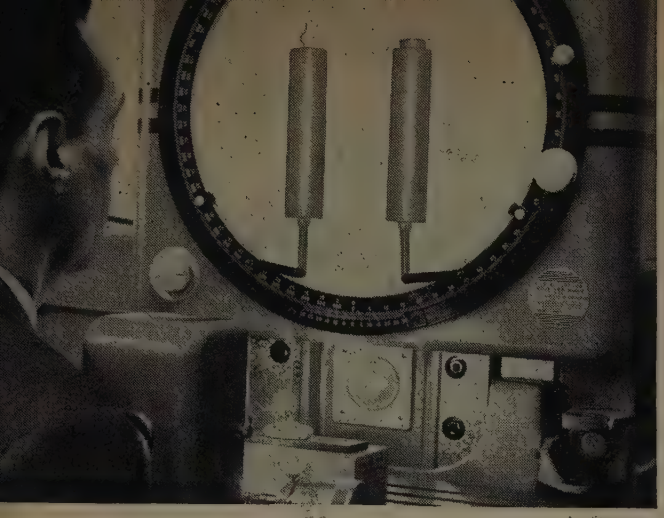
NEW METHODS OF MASS PRODUCTION in G. E.'s germanium products plant* at Clyde, New York are booming diode output to the highest peak in the industry's history. An offspring of the mother plant at Electronics Park, this factory is equipped to produce 12 million diodes a year. Television receivers, computers, communication systems and military requirements present an ever-increasing demand for these minute but vital components.

WITH EXPANDED LABORATORY FACILITIES for the development of new germanium and other semi-conductor items, G. E. is prepared to suggest electronic solutions to your design and manufacturing problems—solutions that may well save you money and improve your product.

Would you like more information on this? Ask us to call. *General Electric Co., Electronics Park, Syracuse, N. Y.*

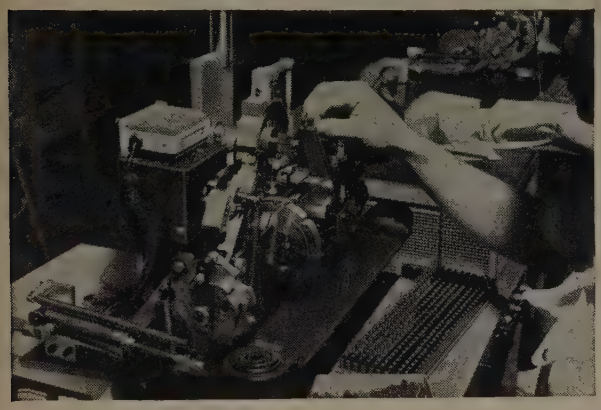
*Which you are invited to inspect when in the Syracuse area. Meanwhile, let us send you additional information and specifications on G-E diode products. Write for bulletin #X57-01A.

4. ORDERLY BANK OF WHISKER MACHINES is typical of modern production facilities in the new G-E plant. Quantities up to 12 million units a year can be produced here.



CONTOUR PROJECTION of diode parts for microscopic spection. Pellet and whisker (on screen) must follow rigid ecifications. This is typical of quality control processes.

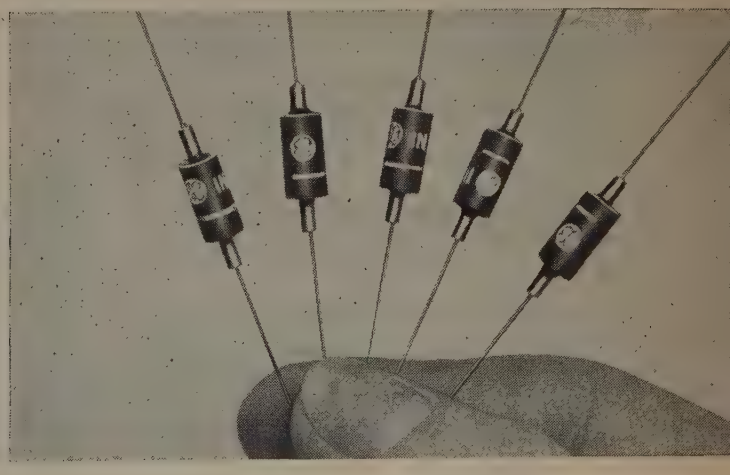
8. AUTOMATIC TEST SEPARATION of diodes by types eliminates costly hand sorting of thousands of units per hour. Every G-E diode is tested many times.



6. FINAL ASSEMBLY of whisker and pellet pins in plastic cases requires special machines designed by G-E engineers for speed and accuracy.

9. HIGH-FREQUENCY TESTING of diodes for television applications has proved successful in supplying over 2 million G-E units to television manufacturers for high efficiency needs.

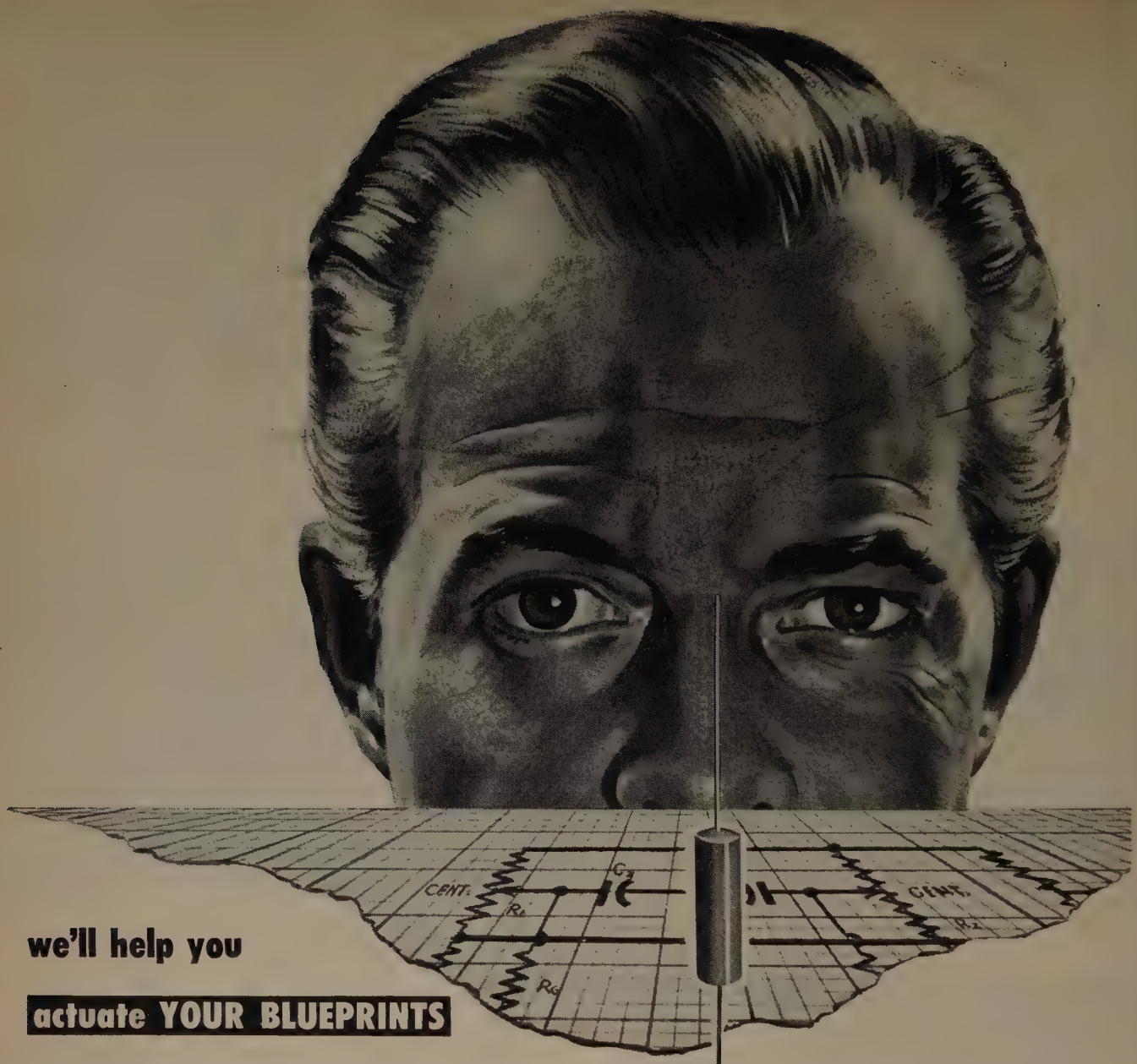
7. ASSEMBLY MACHINES turn out diodes of 12 different varieties. This process represents unusual advancement over former "hand-made" methods.



10. FINISHED G-E DIODES of various types are small, rugged, efficient, and low in cost. These components can replace some categories of vacuum tubes.

You can put your confidence in—

GENERAL ELECTRIC



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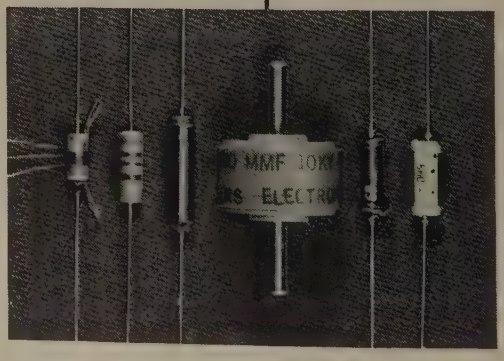

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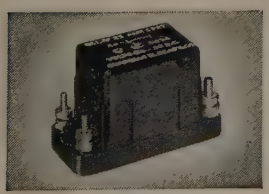

AN-3320-1 D.C.

AN-3324-1 D.C.

Series 595 D.C.

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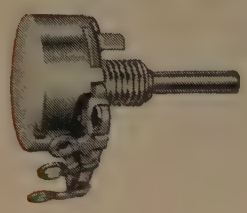
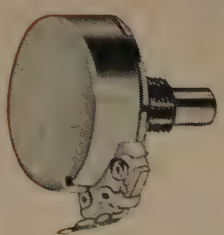
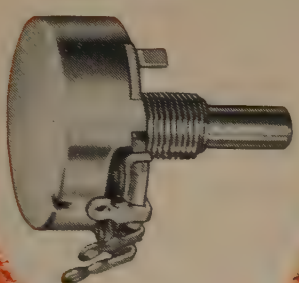


Type 65



Type 90



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+150°C to −55°C

DIAMETER	TYPE 95 1⅛"	TYPE 90 15/16"	TYPE 65 (miniaturized) ¼"
Wattage and Voltage Rating	2 watts @ 70°C with 500 V max. across end terminals	1 watt @ 70°C with 500 V max. across end terminals	½ watt @ 70°C with 350 V max. across end terminals

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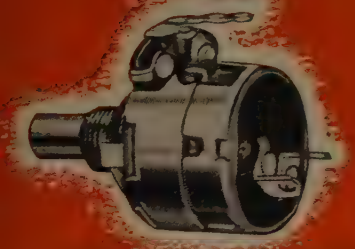
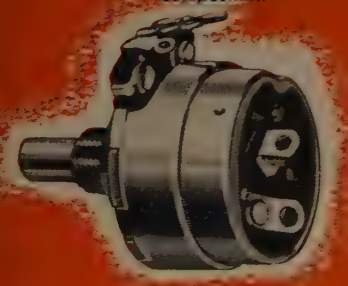
CTS Type 35, 1⅛" Diameter
Composition

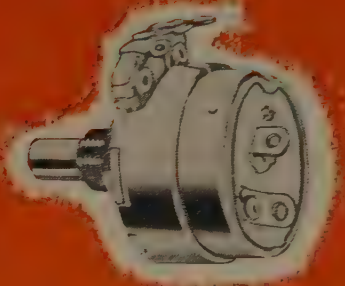


JAN-R-94, Type RV-2B
CTS Type GC 45 with Switch
Composition



JAN-R-94, Type RV-3B
CTS Type GC 35 with Switch
Composition

JAN-R-94, Type RV-2A
CTS Type 45, 15/16" Diameter
Composition

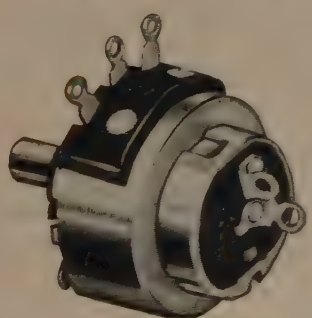


JAN Type RV-4B
CTS Type FGC 95 with Switch
Composition

JAN Type RV-4A
CTS Type 95, 1⅛" Diameter
Composition

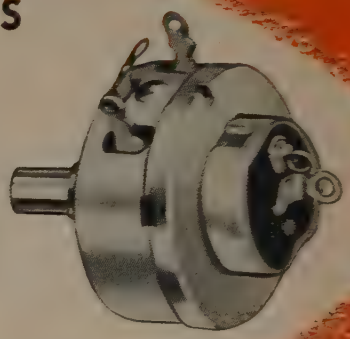
MEETS ALL JAN-R-19 SPECIFICATIONS

JAN Type RA 20A
2 Watt (CTS Type 252)



JAN Type RA 20B
2 Watt (CTS Type GC-252)

JAN Type RA 25A or 30A
3 or 4 Watt (CTS Type 25)



JAN Type RA 25B or 30B
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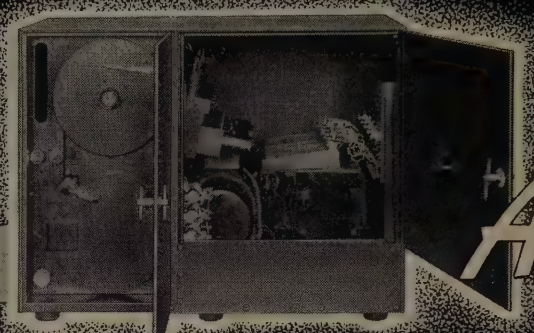

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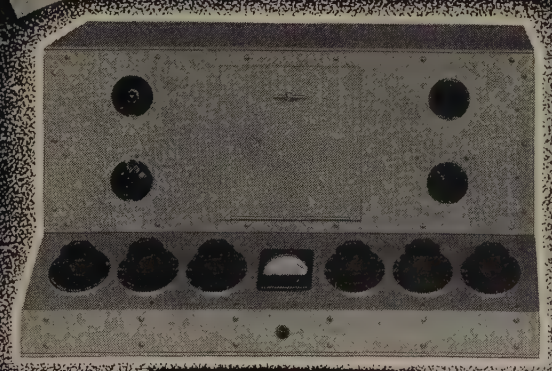

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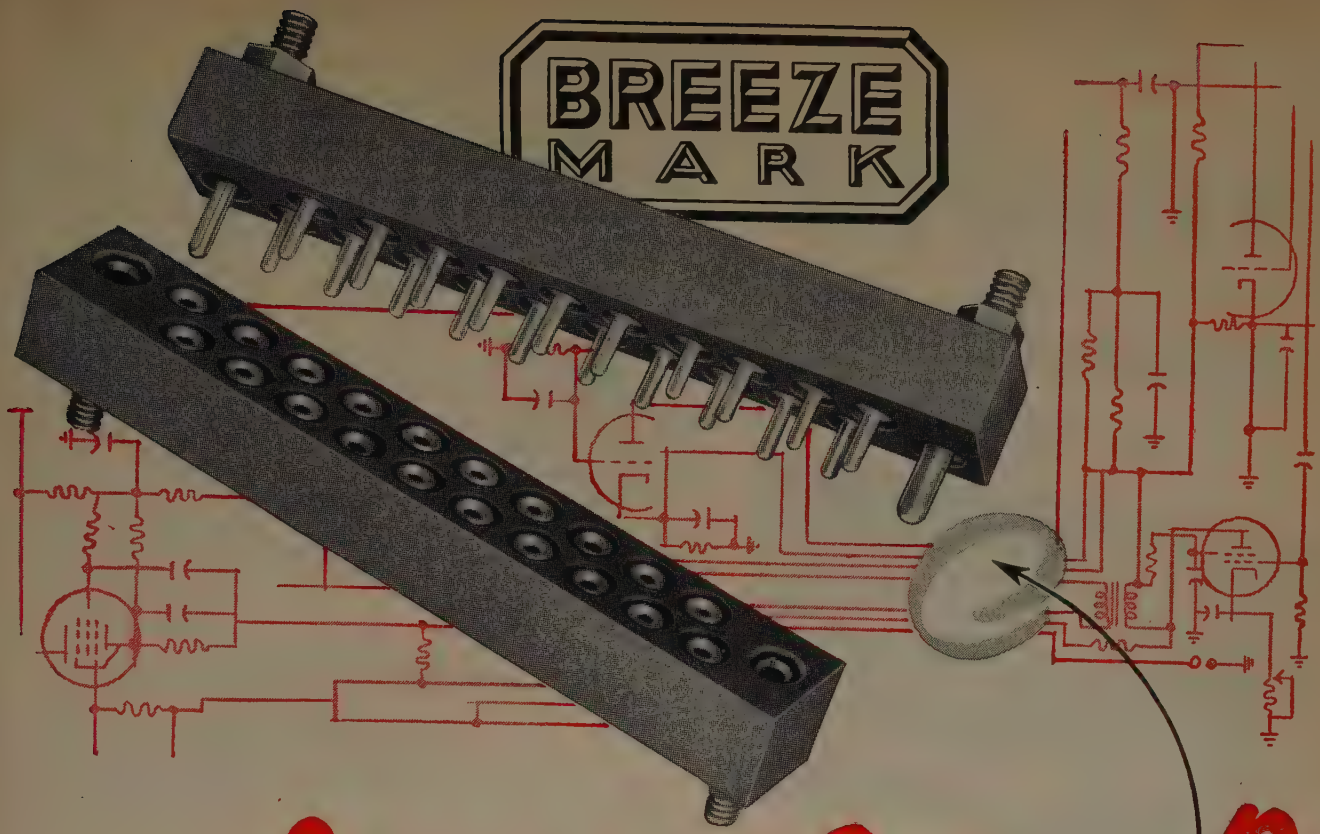
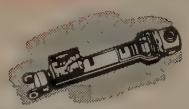


Connector Problem?

...We'll take it from HERE

Good ideas for electronic circuitry sometimes run afoul of connector problems. Maybe existing connector units won't hold air pressure gradients, won't stand the heat, aren't rugged enough for the job. Or maybe it's a question of altitude, or under-water application. But if you can sketch the circuit, we'll take it from there. We've engineered so many special connectors, solved so many "impossible" problems, that whatever the requirements are, we can usually provide the answer.



Lightweight actuators for any requirement.

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Flexible conduit and ignition assemblies.

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Special CONNECTORS

BREEZE CORPORATIONS, INC.

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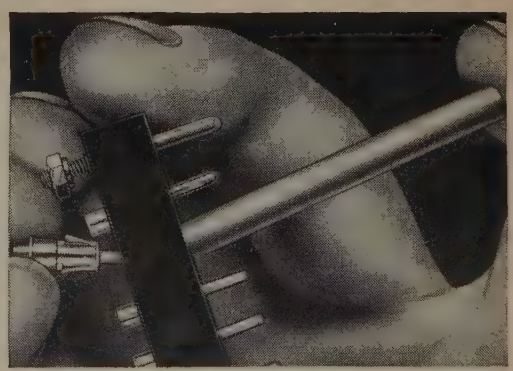

Removable pins in Breeze connectors speed soldering, save time, trouble. Pins snap back into block.

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BRAIN WORK

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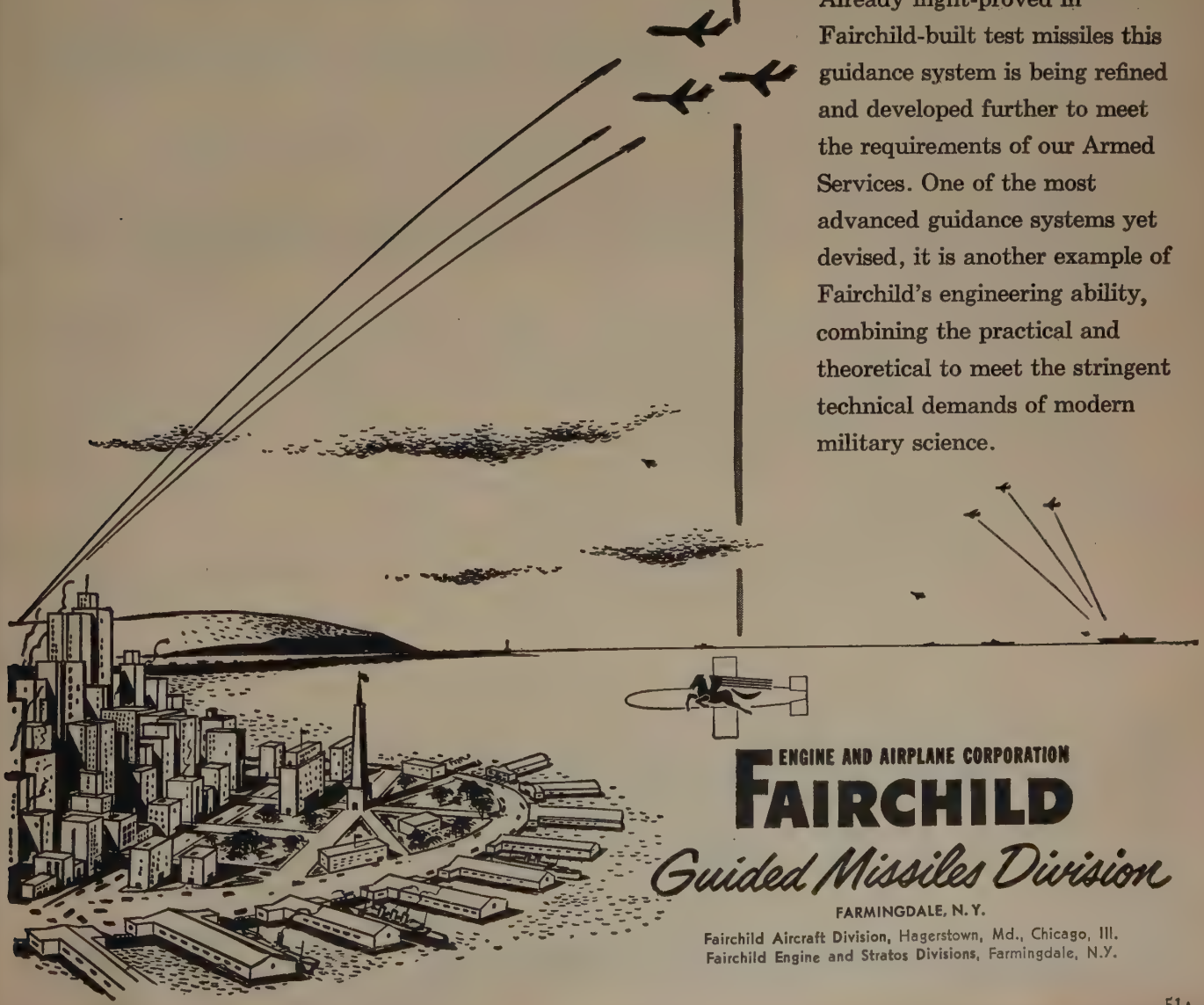
GUIDED MISSILES that become more accurate as they close the range on attacking enemy aircraft are being developed by the Fairchild Guided Missiles Division. Missile experience dating back into World War II has enabled Fairchild engineers to design a guidance system which "homes" on radar echoes reflected from attacking planes and cuts down the margin of error the closer the "bird" gets to its target.

Already flight-proved in Fairchild-built test missiles this guidance system is being refined and developed further to meet the requirements of our Armed Services. One of the most advanced guidance systems yet devised, it is another example of Fairchild's engineering ability, combining the practical and theoretical to meet the stringent technical demands of modern military science.



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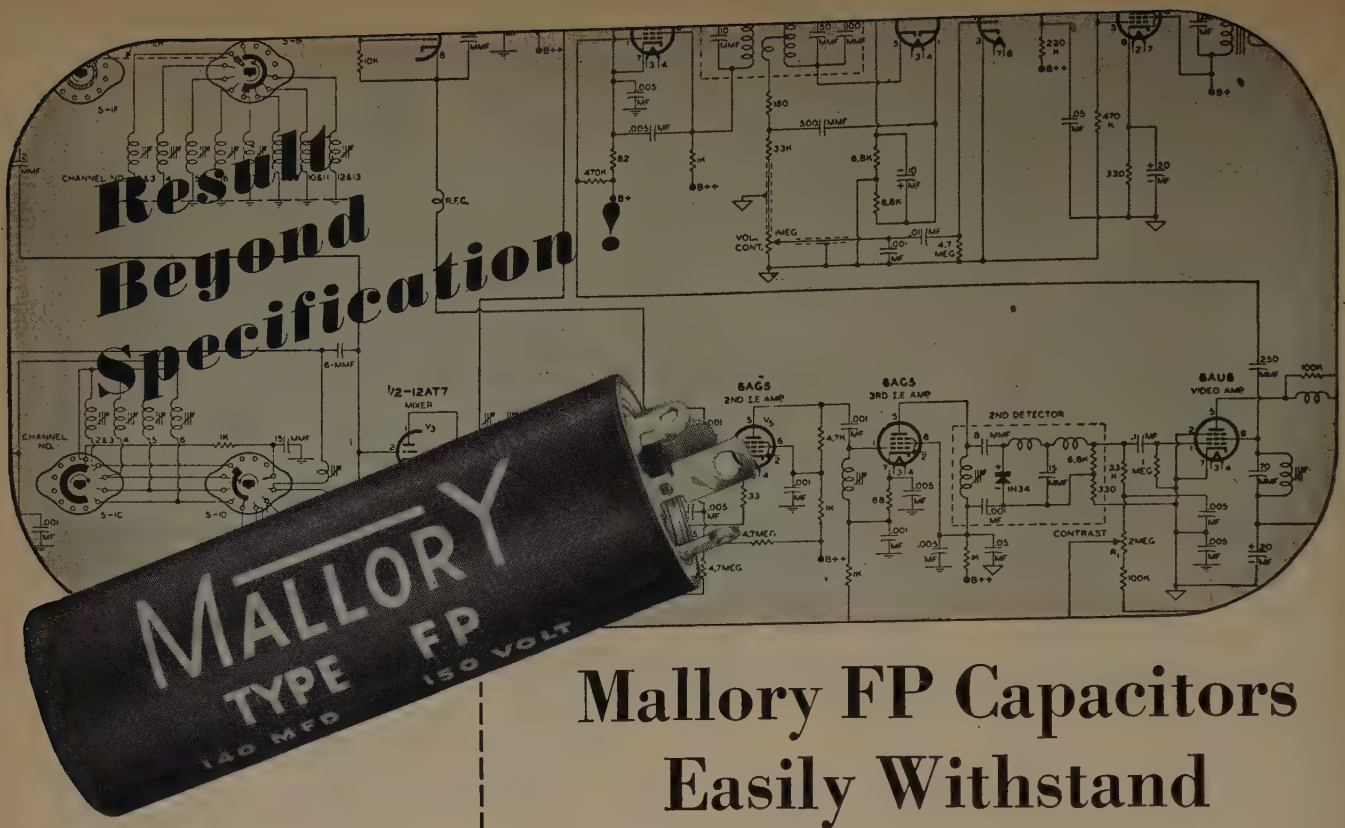

Mallory FP Capacitors Easily Withstand High Ripple Currents In TV Circuits

When you specify Mallory Capacitors for television receivers or other equipment where heat is a problem, you can be sure they will stand the test. Mallory FP Capacitors are designed to give long, trouble-free performance at 85°C. —naturally they give even longer service at normal temperatures. In addition, Mallory FP Capacitors are famous for their long shelf life. Write for your copy of the FP Capacitor Engineering Data Folder.

The superior heat dissipation characteristic of Mallory FP Capacitors —long inherent in our production method—proved to be an important factor in meeting the problem of high ripple currents in TV receivers.

Thorough testing demonstrated that standard Mallory FP Capacitors would stand up in the rugged service involved in the voltage doubling rectifier circuit. The jump from radio ripple currents of about .15 amperes to five or six times this current in TV service places a tremendous burden on capacitors. But Mallory FP Capacitors are giving long, uninterrupted performance . . . at temperatures approximating the boiling point of water.

That's result beyond specification!

Mallory capacitor know-how is at your disposal. What Mallory has done for others can be done for you.

FP is the type designation of the Mallory developed electrolytic capacitor having the characteristic design pictured and famous throughout the industry for dependable performance.

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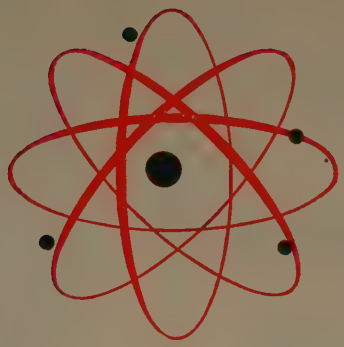

Electronics (Experience + Knowledge) = (Achievement)^n

Factors equalling significant electronics achievement come from long experience and constantly expanding facilities. Our Electronics Division started its record of accomplishment many years ago. Today Air Associates is recognized as a major supplier of airborne, marine, and ground electronics equipment for United States and allied governments.

Designing and developing critically needed electronic units and producing the material is our business! Your inquiry to Teterboro will receive prompt attention.

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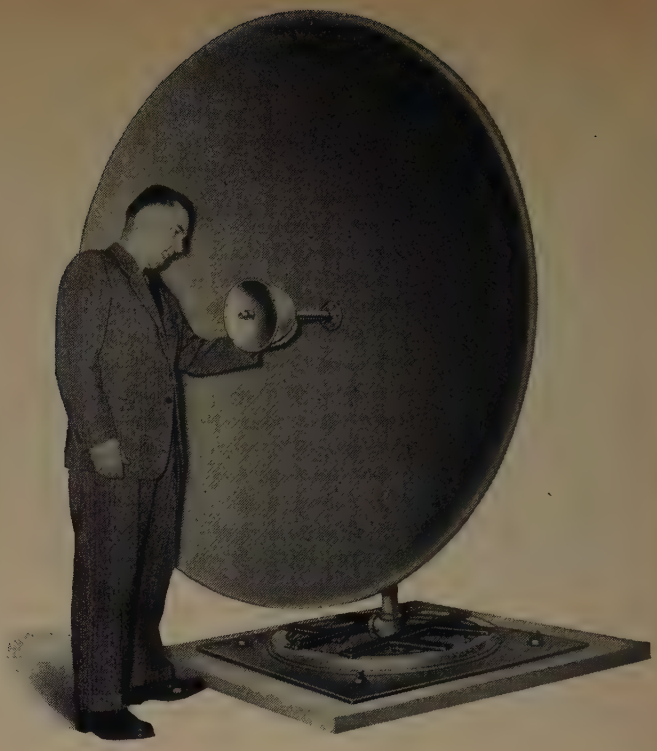
SERVING THE NATION IN AVIATION

940 MCS

TOP PERFORMANCE



Parabolic Antennas for 940 mcs.

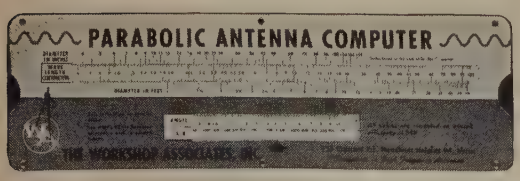
and every other Microwave Frequency

The Workshop was the first manufacturer to bring out a complete line of parabolic antennas for all microwave frequencies. Having specialized in this field for several years, we can supply equipment from our standard line to meet the majority of installations. However, for special requirements, we are equipped to design and supply reflectors in a wide range of sizes and focal lengths.

Model 940

Frequency Range	920 to 960 Mcs.			
Input Impedance	52 ohms nominal			
VSRW	1.20 to 1 over the band			
Power Rating	1 kw. continuous			
Polarization	Either vertical or horizontal available at time of installation.			
Reflector Size	4′	6′	8′	10′
Gain (db, approx., over isotropic radiator)	19	23	26	28
Half Power Angles (H plane)	17.75°	11.75°	8.6°	6.9°
(E plane)	19.75°	12.9°	9.6°	7.8°
Side Lobes	17 db down or better			
Pressurized	Feed can be pressurized to 10 lbs. p.s.i.			
Input Connection	Weatherproof type "N" fitting; special fittings are available for RG-8/U, RG-17/U or 7/8″ copper line. Specify when ordering.			
De-icing	Available for all models. Capacities range from 400 to 4000 watts.			

FREE SLIDE RULE



This pocket size slide rule quickly computes diameter, wavelength, angle and gain for parabolic antennas. Reverse side carries FCC frequency allocations conversion tables and other data. Write for your copy.

OTHER STANDARD MODELS

MODEL NO.	FREQUENCY (MCS.)	GAIN* (DB.)	HALF POWER ANGLE E Plane*	H Plane*
2000	1700–2300	27.0–34.5	10.28–3.65	9.2 –3.25
7000	5925–7425	36.0–43.0	3.24–1.36	2.86–1.21

*Gain and Half Power Angles are dependent on size and frequency of parabolas,—4, 6, 8 or 10 foot diameter.

Write for Parabolic Antenna Catalog

The WORKSHOP ASSOCIATES

DIVISION OF THE GABRIEL COMPANY

Specialists in High-Frequency Antennas

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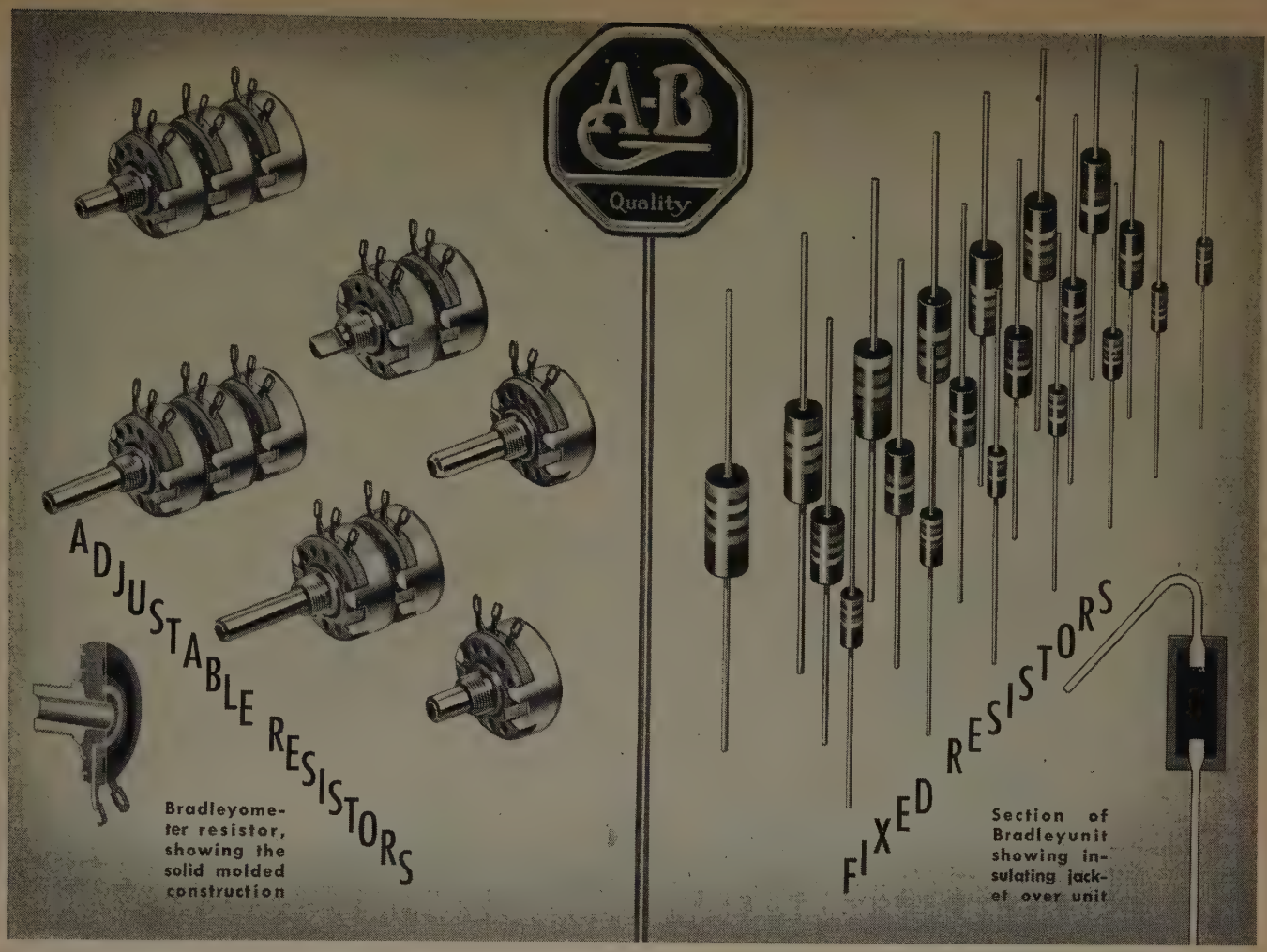


CONSISTENT PERFORMANCE UNDER ALL ATMOSPHERIC CONDITIONS

BRADLEYOMETERS—Available as rheostats or potentiometers with any type of resistance rotation curve up to 5 megohms. Rated at 2 watts.

Available in single, dual, or triple unit assemblies, with or without line switch.

Resistor element is molded as a single piece, with terminals, faceplate, and bushing molded together in one piece. Shaft and casing are made of stainless steel. Send for dimension sheet and performance curves, today.

BRADLEYUNITS—Available in ½-watt, 1-watt, and 2-watt ratings in standard R.T.M.A. values up to 22 megohms.

Rated at 70C ambient temperature . . . not 40C. Under continuous full load for 1000 hours, resistance change is less than 5 per cent. Require no wax impregnation to pass salt water immersion tests. Differentially tempered leads prevent sharp bends near resistor.

Packed in honeycomb cartons to prevent tangling of leads during assembly operations.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis.

A-B Quality

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

Sold exclusively to manufacturers QUALITY of radio and electronic equipment

German crowd, part of the 1,250,000 from East and West Berlin, sees a typical RCA television program.

"Freedom's window in the Iron Curtain"

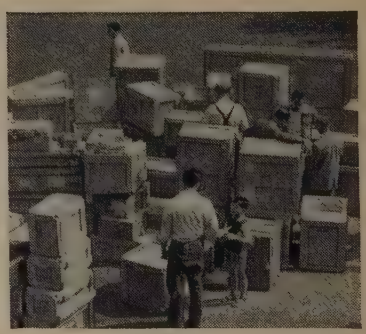
You've read the story of last summer's TV demonstrations in Berlin. It attracted a million and a quarter Germans—including thousands who slipped through the Iron Curtain to see Western progress at work.

Behind this is another story: How RCA engineers and technicians broke all records in setting up these Berlin facilities. The project called for a TV station and studio, a lofty batwing antenna, and the installation of 110 television receivers at strategic points. Such a program would normally take several months to complete. It was installed and put to work by RCA in a record-breaking 85 hours!

Programs witnessed by Berliners included live talent shows, sports events, news commentaries, and dramatizations of the Marshall Plan. Observers pronounced reception fully up to American standards—another impressive demonstration of democracy's technical ingenuity and leadership.

* * *

See the latest wonders of radio, television, and electronics at RCA Exhibition Hall, 36 West 49th St., New York. Admission is free. Radio Corporation of America, RCA Building, Radio City, N. Y. 20, N. Y.

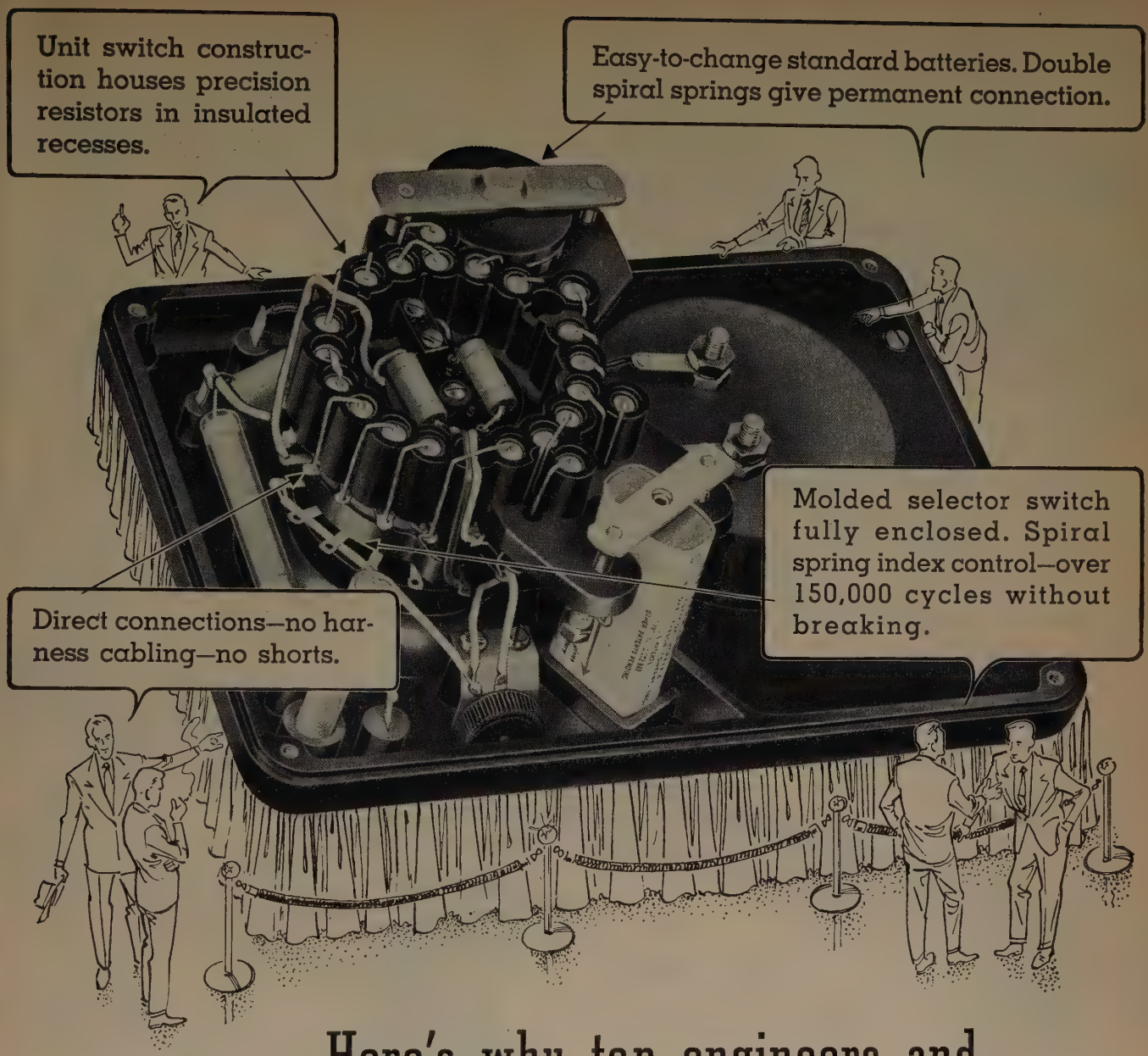


Part of the 401 cases of RCA equipment shipped to Berlin for television demonstrations.

RCA

RADIO CORPORATION of AMERICA

World Leader in Radio—First in Television


Unit switch construction houses precision resistors in insulated recesses.
Easy-to-change standard batteries. Double spiral springs give permanent connection.
Molded selector switch fully enclosed. Spiral spring index control—over 150,000 cycles without breaking.
Direct connections—no harness cabling—no shorts.

Here's why top engineers and technicians use Model 630

Features like those shown above are what make this popular V.O.M. so outstandingly dependable in the field. The enclosed switch, for instance, keeps the silvered contacts *permanently clean*. That's rugged construction that means stronger performance, longer life. And tests show that the spiral spring index control, after more than 150,000 cycles of switch rotation, has no disruption or appreciable wear! Investigate this history-making Volt-Ohm-Mil-Ammeter today: 33 ranges, large 5½" meter.

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The Fountainhead of Modern Tube Development is RCA

Pulse-rated

Four RCA tubes specifically designed for pulsed applications

RCA-5893 "Pencil-Type" UHF Triode

RCA-5893 is a new, medium-mu, "pencil-type" triode employing a double-ended, coaxial-electrode structure. As a plate-pulsed oscillator in grounded-grid service, the 5893 will deliver a useful power output at peak of pulse of 1200 watts at frequencies up to 3300 Mc.

Maximum Ratings as Plate-Pulsed Oscillator

For max. total "on" time, in any 5000-μsec interval, of 5 μsec

Peak Positive-Pulse Plate Supply Voltage	1750 max. volts
Peak Negative-Pulse Grid-Bias Voltage	150 max. volts
Peak Plate Current from Pulse Supply	3 max. amp
Peak Rectified Grid Current	1.3 max. amp
Plate Dissipation	6 max. watts
Pulse Duration	1.5 max. μsec

RCA-5946 UHF Power Triode

RCA-5946 is a new forced-air-cooled power triode for use in circuits of the coaxial-cylinder type. In plate-pulsed service, the 5946 will deliver a useful power output at peak of pulse of 14 kw at a frequency of 1250 Mc.

Maximum Ratings as Plate-Pulsed Oscillator & Amplifier

For max. total "on" time, in any 1000-μsec interval, of

	10 μsec	100 μsec
Peak Positive-Pulse Plate Supply Voltage	7500 max.	7500 max. volts
Peak Negative-Pulse Grid-Bias Voltage	600 max.	600 max. volts
Peak Plate Current from Pulse Supply	4.5 max.	3.5 max. amp
Peak Rectified Grid Current	1.0 max.	0.75 max. amp
Plate Dissipation	250 max.	250 max. watts

RCA-4C33 UHF Power Triode

RCA-4C33 is a forced-air-cooled power triode for coaxial-type circuits. For plate-pulsed service, it will provide a power output at peak of pulse of 130 kw at a frequency of 600 Mc.

Maximum Ratings as Plate-Pulsed Oscillator

Peak Positive-Pulse Plate Supply Voltage	13000 max. volts
Peak Negative-Pulse Grid-Bias Voltage	2000 max. volts
Peak Plate Current from Pulse Supply	30 max. amp
Peak Rectified Grid Current	4 max. amp
Plate Dissipation	250 max. watts
Pulse Duration	5 max. μsec

RCA-3E29 Twin-Beam Power Amplifier

RCA-3E29 is a twin-unit, beam power amplifier designed to handle a peak plate current of 10 amp. in pulse modulation service.

Maximum Ratings as Pulse Modulator (both units in parallel)

For pulse length of 1 max. | 1.2 max. μsec

DC Plate Supply Voltage	5000 max.	5000 max. volts
DC Grid-No. 2 Supply Voltage	850 max.	850 max. volts
DC Grid-No. 1 Supply Voltage	−200 max.	−200 max. volts
Plate Input	85 max.	60 max. watts
Peak Grid-No. 2 Current	0.5 max.	0.5 max. amp
Plate Dissipation	15 max.	15 max. watts

For further technical data or design assistance on any RCA pulse tube, write RCA, Commercial Engineering, Section 47LR, Harrison, N. J., or contact the RCA Field Office nearest you.

FIELD OFFICES: (EAST) Humboldt 5-3900, 415 S. 5th St., Harrison, N.J. (MIDWEST) Whitehall 4-2900, 589 E. Illinois St., Chicago, Ill. (WEST) Madison 9-3671, 420 S. San Pedro St., Los Angeles, Calif.

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Grade	Background Color
Fellow	Gold
Senior Member	Dark Blue
Member	Light Blue
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Student	Green

The lapel button has a screw back with jaws which grip the cloth of the coat. These are priced at $3.00 each. The pin, at $3.50 each, is provided with a safety catch. The watch charm, enameled on both sides and equipped with a suspension ring for attaching to a watch charm or fob, is $5.50.

Prices on emblems are the same for all grades of membership and include Federal tax, postage, and insurance or registered-mail fee.

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Please do not send cash except by registered mail.

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48 IRE 22. S2 Standards on Television: Definitions of Terms, 1948. (iv+4 pages, 8½×11 inches)	$0.50
50 IRE 23. S1 Standards on Television: Methods of Measurement of Television Signal Levels, Resolution, and Timing of Video Switching Systems, 1950. Reprinted from the May, 1950, PROCEEDINGS (pp. 551–561)	$0.70
50 IRE 23. S2 Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950. Reprinted from the November, 1950, PROCEEDINGS (pp. 1258–1263)	$0.75
50 IRE 23. S3 Standards on Television: Methods of Measurement of Electronically Regulated Power Supplies, 1950. Reprinted from the January, 1951, PROCEEDINGS (pp. 29–35)	$0.75
50 IRE 24. S1 Standards on Wave Propagation: Definitions of Terms, 1950. Reprinted from the November, 1950, PROCEEDINGS (pp. 1264–1268)	$0.60
45 IRE 24. S1 Standards on Radio Wave Propagation: Definitions of Terms Relating to Guided Waves, 1945. (iv+4 pages, 8½×11 inches)	$0.20
Normas Sobre Receptors de Radio, 1938.* A Spanish-language translation of "Standards on Radio Receivers, 1938," by the Buenos Aires Section of The Institute of Radio Engineers. (vii+64 pages, 6×9 inches)	**Two Argentine Pesos (Postpaid)**

* Not carried in Stock at IRE Headquarters in New York. Obtainable only from Señor Domingo Arbó, Editor of *Revista Telegrafica*, Peru, 165, Buenos Aires, Argentina.

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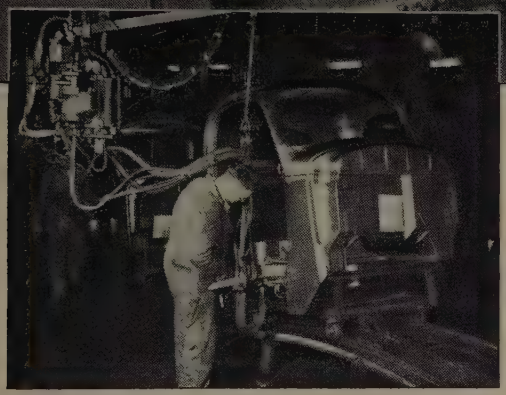
INCLUDE REMITTANCE WITH ORDER AND ADDRESS.

THE INSTITUTE OF RADIO ENGINEERS, INC.
1 East 79 Street, New York 21, New York

IGNITRONS ARE NEWS!

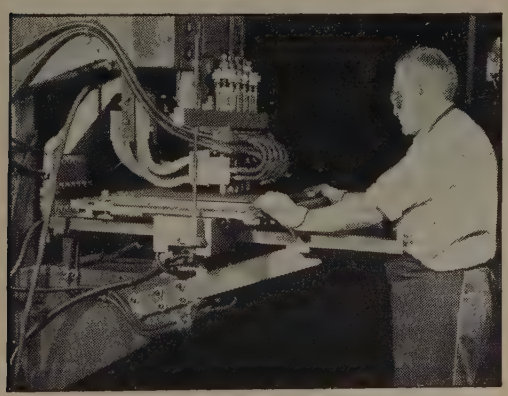


● G-E ignitrons control resistance welders of all types, in all industries. The newest field of application is 3-phase welding.

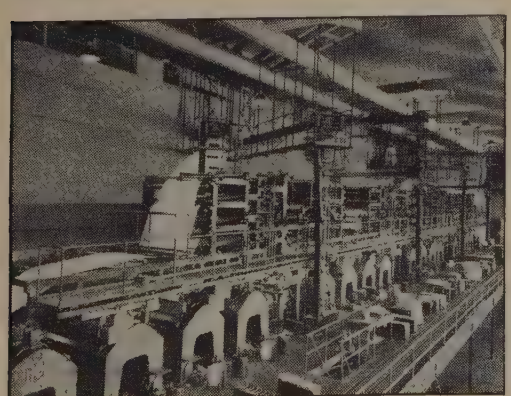
IGNITRONS are doing more and more BIG jobs! As an electronic designer, it will profit you to know the full, wide scope of these tubes in industry, because —having no moving parts—ignitrons need no mechanical upkeep.

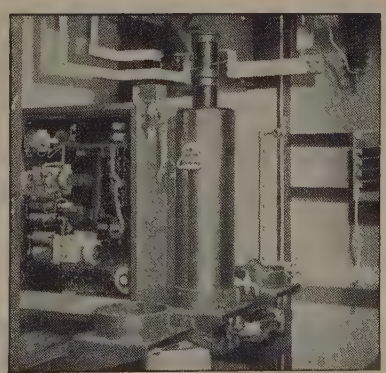
SERVICE LIFE IS SO LONG it may be measured in years. Ignitrons are steel tubes, tough and shock-resistant!

STURDINESS AND VERSATILITY are such that new uses for ignitrons are constantly developing. One important application today is 3-phase welding control. G.E. has off the press a new descriptive bulletin on Ignitron GL-5822—a tube specially designed for 3-phase welding. Wire or write for ETD-157. *Electronics Division, Section 8, General Electric Company, Schenectady 5, N. Y.*

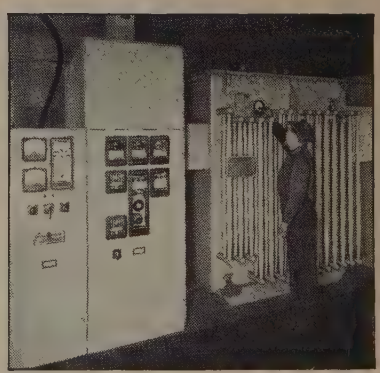


● G-E ignitrons regulate large d-c motors, such as those which drive this *Dallas News* press shown below.





● G-E ignitrons serve in high-voltage rectification. Example: this special synchrotron power-supply unit for M.I.T.

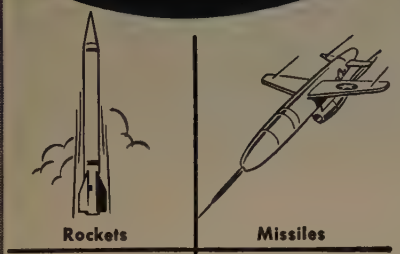


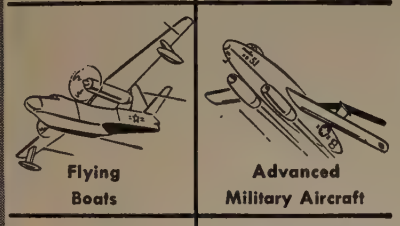
● G-E ignitrons serve in low-voltage power rectification, as in this mining type rectifier for Vinton Coal and Coke Company.

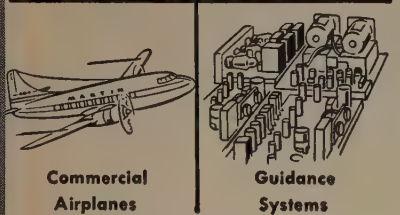
GENERAL ELECTRIC

180-K4

VARIETY
spices the life of
ENGINEERS
working with
Martin







Opportunities for Electronics Engineers

One of the country's leaders in airborne electronic research since before V-J Day, The Glenn L. Martin Company needs engineers with experience in research and development of radar, television, pulse and display circuits ...and, in the electro-mechanical field, experienced engineers in armament, servo - mechanisms, electrical work, rocket propulsion and special weapons or systems design.

• • •

Martin has the greatest diversity of projects of any aircraft company in the East. Offers greater opportunities for development, career positions for qualified engineers. Submit strictly confidential resume outlining qualifications in detail. Personal interviews will be arranged.

THE GLENN L. MARTIN CO.
Technical Employment • Baltimore 3, Md.

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

ELECTRONIC TECHNICIANS

Several permanent openings calling for skill at chassis layout, wiring techniques and verifying circuitry. Work in new, well-equipped plant on precision counting and computing equipment with proven peace-time as well as military prospects. Organization comfortably small and steadily growing. Write Potter Instrument Company, Inc. 115 Cutter Mill Road, Great Neck, N.Y.

ELECTRONIC ENGINEERS

Small electronic research and development laboratory, located 8 miles outside of Washington, D.C. has several openings for junior and senior electronic engineers. Degree essential. Varied projects include analog computers, servomechanisms, special test equipment, etc. All defense work. Liberal salaries dependent upon experience. Write Box 673.

SENIOR ELECTRONIC ENGINEER

At least three years' post-college experience in development, DC amplifier, digital computers, pulse and servo design. Established company, New York City. Box 681.

(Continued on page 72A)

COLLINS RADIO COMPANY

Western Division

BURBANK, CALIFORNIA

Openings available for three Engineers with experience in communications and control work.

Minimum requirements: B.S. degree and four years of sound technical experience.

These openings require treatment of both theoretical and practical problems of considerable difficulty and only those with a real interest in the technical aspects of Engineering should apply.

Send resumes to

2700 West Olive Avenue
BURBANK, CALIFORNIA

SALES ENGINEER

OUR long term planning has led to a decision to add a Sales Engineer to our staff. We need an experienced man to call on key customers in the New York, New Jersey area and to advise us on their new equipment needs. He will have other interesting sales assignments.

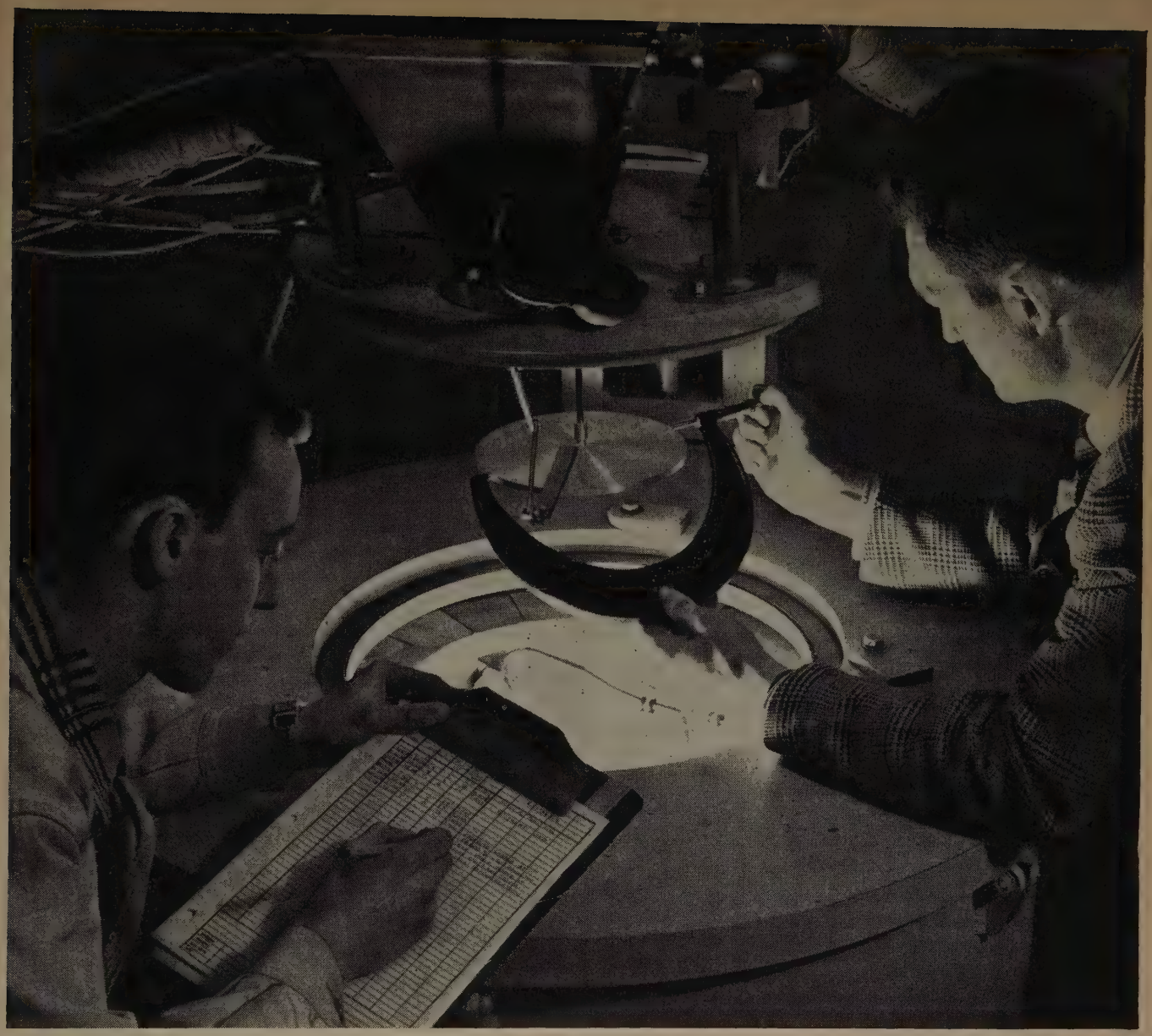
Applicant should have a B.S. in EE or its equivalent—engineering experience, test equipment design and technical sales experience covering a period of 8 to 10 years is desirable.

We are a stable, well established small firm located in a desirable residential area—salary will be commensurate with ability and you'll find room for all your talents.

BOONTON RADIO CORP.

Please write, including educational and experience record, and salary desired to Sales Manager.

BOONTON, NEW JERSEY



Do you want a career with a future?

More and more of America's outstanding engineers are carving fine careers for themselves at Boeing. They've found a future here in an Engineering Division that's been growing steadily for over 35 years.

If you measure up, there's great opportunity here for you, too, and the rewarding experience of working on some of the nation's most vital programs such as the B-52 and B-47 jet bombers, guided missiles and other revolutionary developments.

You'll associate with men of the highest engineering renown, men who can help you further your own professional standing. You'll find here research facilities that are among the world's finest. And you'll enjoy a good salary that grows with you.

Needed now in Seattle are experienced and junior aeronautical, mechanical, electrical, electronics, civil, acoustical, weights and tooling engineers for design and research; servo-mechanism designers and analysts; and physicists and mathematicians with advanced degrees. (More *housing is available in Seattle than in most other major industrial centers.)*

Or, if you prefer the Midwest, similar openings are available at the Boeing Wichita, Kansas, Plant. Inquiries indicating such a preference will be referred to the Wichita Division.

Write today to the address below or use the convenient coupon.

JOHN C. SANDERS, Staff Engineer—Personnel
Dept. J-12
Boeing Airplane Company, Seattle 14, Wash.

Engineering opportunities at Boeing interest me. Please send me further information.

Name _____

Address _____

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FIRST Supersonic Aircraft (X-1)

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Scientific or engineering degree and extensive technical experience required.

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Research Physicists

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With Advanced Academic Training and Several Years' Experience

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Research and Development

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Our Long Range Programs and Steady Growth Assure Permanent Employment at Excellent Salaries for Competent and Qualified Personnel.

Interested Persons Are Invited to Submit Detailed Resumes of Experience and Education with Salary Requirements and Availability Date to:

The Employment Department
CAPEHART-FARNSWORTH CORPORATION
FORT WAYNE 1, INDIANA

POSITIONS OPEN

(Continued from page 70A)

PHYSICISTS AND ENGINEERS

Southwest Research Institute has several permanent staff positions for physicists and engineers with B.S. or advanced degrees and 2 to 10 years' experience in acoustics, HF and VHF antenna design, electro-mechanical transducer research, optical instruments, and pulse circuits. Send statements of qualifications and interests in industrial and defense research to: Physics Dept., Southwest Research Institute, Essar Ranch, San Antonio 6, Texas.

ENGINEER

Thoroughly experienced in development and production of current regulator tubes as used in GRC series of military sets. Able to organize, supervise complete dept. Send résumé to Box 674.

ENGINEERS, PHYSICISTS AND MATHEMATICIANS

Digital Computer Laboratory, Project Whirlwind, Massachusetts Institute of Technology has several staff openings for above average research and development engineers, physicists and mathematicians, either with or without experience. Development and application of new equipment using transistor circuits, ferromagnetic and ferroelectric storage, magnetic drums, transmission of coded information, analog-digital data conversion. Position carries opportunity for academic study. Salary appropriate to candidate's experience and training. Address 211 Massachusetts Ave., Cambridge, Mass.

(Continued on page 73A)

MICROWAVE ENGINEER

Excellent opportunity with good salary, in growing concern for experienced microwave plumber, capable of R.F. and Antenna Design. Financial assistance given engineer willing to relocate in Boston area.

Address résumé to:

TRANSDUCER CORPORATION

1085 Commonwealth Avenue

Boston, Massachusetts

Electronic Subsidiary of

AMERICAN MACHINE & FOUNDRY CO.

TRANSMISSION-EQUIPMENT-DESIGN-ENGINEERS

West Coast manufacturer of carrier equipment plans expansion program in United States and Canada. Wishes to contact a small number of experienced telephone and telegraph engineers interested in permanent positions offering excellent futures in a well-established but expanding industry.

Several positions will become available during the next year. Salaries commensurate with training and experience will be arranged for men selected. Please give full details in first reply.

Lenkurt

Lenkurt Electric Co.
1105 County Rd., San Carlos, Calif.
926 East Hastings St., Vancouver, B.C.

POSITIONS OPEN

(Continued from page 72A)

ENGINEERS AND PHYSICISTS

Engineers and physicists with educational background in mechanical, electrical or electronic engineering, physics or engineering physics for research and advanced development in plant and laboratory instrumentation, geophysics, physical measurements and industrial electronics. Prefer man with 5 to 15 years' experience in experimental research, design and development of instruments, intricate mechanisms, electronic apparatus, optical equipment, servomechanisms and allied fields. Positions are of immediate and permanent importance to our operations. Southwestern location in medium sized community; excellent employee benefits. Please give age, experience, and other qualifications in reply. Write Personnel Director, Research & Development Dept., Phillips Petroleum Co., Bartlesville, Oklahoma.

ELECTRONIC ENGINEER OR PHYSICIST

B.S. with electronic training to operate and maintain ionospheric recorder and interpret data. Also assist in propagation and aurora studies. Location near Fairbanks, Alaska. No experience necessary. Salary $4500-$5000. Interested parties write airmail to Dr. Wm. S. Wilson, Acting Director, Geophysical Institute, University of Alaska, College, Alaska.

(Continued on page 74A)

ELECTRICAL ENGINEERS

(Senior)

Experienced in Design and Development Work in the fields of:

- GYROSCOPICS
- ANALOG COMPUTERS
- FIRE CONTROL SYSTEMS
- SERVO MECHANISMS
- INSTRUMENT DESIGN
- CONTROL CIRCUITS

or Experienced in:

- TECHNICAL WRITING

Applicants should have BS or MS degree with a minimum of 3 to 5 years' Experience.

Successful Applicants will be Offered Good Starting Salaries. Permanent Positions with Opportunity for Advancement and Professional Growth.

Reply by sending complete resume to

TECHNICAL PERSONNEL OFFICE

ARMA CORP.

254 36th St., Brooklyn 32, N.Y.

POSITIONS OPEN

Location
Kansas City, Mo.

Electronic & Mechanical Engineers

ELECTRONIC ENGINEERS: Must have considerable development experience in radio transmitting and receiving equipment. Ability to fill position of Senior Project Engineer a requisite.

MECHANICAL ENGINEER: Must have development experience in mechanical design of electronic or similar precise equipment. Practical and theoretical knowledge of materials, finishes, sheet metal, and machine shop design are basic requirements. Position is one of considerable responsibility.

SALARY: Open

These positions are permanent.

Write stating educational and professional history direct to:

JAY V. WILCOX, *President*

WILCOX ELECTRIC COMPANY, INC.
1400 Chestnut St., Kansas City 1, Mo.

Dependable communications since 1931

ENGINEERS

Unusual Opportunities and Salaries

Exist on project and product engineering work for Graduate Engineers with Design, Development and Product experience in any of the following:

Analogue Computers
Radar
Communication Equipment
Hydraulics
Electronic Packaging
Pulse Transformers
Servo Mechanisms
Electronic Circuits
Aircraft Controls
Instrumentation
Printed Circuits
Fractional H P Motors
Vacuum Tube Techniques

Submit Résumé To Employment Office

SPERRY

SPERRY GYROSCOPE CO.
DIVISION OF THE SPERRY CORP.
GREAT NECK, L.I., NEW YORK

ATOMIC ENERGY INSTALLATION

NEEDS

ELECTRONIC ENGINEERS

Two to ten years' experience in research, design, development or test. Patent history desirable but not necessary. A variety of positions open for men with Bachelor's or advanced degree qualified in one or more of the following fields:

- RELAYS
- TELEMETERING
- PULSE CIRCUITS
- UHF TECHNIQUES
- SERVO-MECHANISMS
- INSTRUMENTATION
- QUALITY CONTROL
- LOW POWER APPLICATION
- TEST EQUIPMENT RELATING TO ABOVE FIELDS

■

TECHNICAL WRITERS

Experienced in preparation and publication of standards, electronic and mechanical technical manuals. Engineering background necessary.

■

JOB ANALYSTS

Mechanical and electrical engineers experienced in job evaluation and other wage administration activities.

■

PHYSICISTS

With background of pure physics.

●

STANDARDS ENGINEERS

Experienced in writing specifications, in liaison work, and in correlating design information to accepted standards. Aircraft industry experience desirable.

●

These are PERMANENT POSITIONS with Sandia Corporation in Albuquerque, New Mexico. The Laboratory is operated by Sandia Corporation, a subsidiary of Western Electric Company, under contract with the ATOMIC ENERGY COMMISSION. This laboratory offers good working conditions and liberal employee benefits including paid vacations, sick leave, and a retirement plan.

■

Albuquerque, center of a metropolitan area of 35,000, is located in the Rio Grande Valley, one mile above sea level. The "Heart of the Land of Enchantment," Albuquerque lies at the foot of the Sandia Mountains, which rise to 11,000 feet. Climate is sunny, mild and dry the year 'round. No housing shortage in Albuquerque area.

MAKE APPLICATION TO

Professional Employment

SANDIA CORPORATION

SANDIA BASE

ALBUQUERQUE, N.M.

(Continued from page 73A)

PROJECT ENGINEER

Project engineer to take charge of research project in Aero Engineering Dept. of the University of Minnesota. Must have M.S. in Aero Engineering (Ph.D. preferred) and a minimum of 5 years' experience. Excellent opportunity for man interested in doing further graduate work. Housing available. Liberal employee benefits. Submit details of background to Mr. Francis Womack, Admin. Assist., Rosemount Research Labs., Rosemount, Minnesota.

ELECTRONIC ENGINEERS AND TECHNICIANS

Voice of America announces a need (New York City and overseas) for experienced electronic engineers and technicians. Send applications (standard form 57) to: U. S. Dept. of State, Personnel Branch, 1790 Broadway, 16th floor, New York 19, N.Y. (Do not telephone.)

ELECTRONIC ENGINEER

Electronic engineer, $5400 per annum. Responsible for maintenance and overhaul engineering of guided missile electronic equipment, including preparation of technical manuals for guidance of all aircraft overhaul activities throughout the Naval service. Write or contact in person to Employment Office, Room 0015-A, Main Navy Bldg., Washington, D.C.

ENGINEERING SALES—INDUSTRIAL CONTROL

Interesting and well paid opportunity with small company in northern New Jersey, a leader in the industrial electronic control tube field. Requires extensive travel, principally in the middle west after adequate training period. Prefer graduate electronic engineer with interest in circuit design, and 1 to 7 years' working experience. Reply Box 677.

ELECTRICAL ENGINEER OR PHYSICIST

Progressive young New England company desires electrical engineer or physicist familiar with pulse techniques and electronic equipment as applied to nuclear research instruments. Ample capital and volume of business to support man of highest training and caliber. Reply Box 678.

PROFESSORS

The Technion (Institute of Technology, Haifa, Israel) proposes to appoint two full professorships and two associate professorships to faculty of electrical engineering. Applicants must have specialized professional and academic qualifications in telecommunications and power engineering. Be willing to integrate themselves into the life of the country and, in due course, teach Hebrew. Applications with full details should be sent, for transmission to Haifa, to the American Technion Society, 154 Nassau St., New York 38, N.Y.

ELECTRICAL ENGINEER

New transformer and electronic specialty firm located in upstate New York has opening for young electrical engineer to grow with the company. Applicants should have B.S. in E.E. and an interest in instrumentation. Box 680.

(Continued on page 100A)

POSITIONS AVAILABLE

GRADUATE

ELECTRONIC ENGINEERS

EXPERIENCE IN DESIGN AND DEVELOPMENT PREFERRED

FOR PROJECTS IN THE FIELDS OF

"TELEMETERING" AND "RADIO CONTROL"

PROJECTS WITH EXCELLENT PEACETIME APPLICATION

Give experience, education, age, salary expected. Please be complete and specific. All inquiries will be considered promptly and kept confidential.

Write to Personnel Director

RAYMOND ROSEN

ENGINEERING PRODUCTS, INC.

32ND & WALNUT STREETS

PHILADELPHIA 4, PA.

ENGINEERS PHYSICISTS

A major expansion of THE JACOBS INSTRUMENT COMPANY has made available a number of positions for men qualified to take responsibility as Section Heads. A minimum of five years of experience, plus an outstanding record of achievement, is required. Experience should be in high frequency circuit design, systems studies, aircraft instruments, aerodynamics, servomechanisms, gyroscopes, optical instruments, missile guidance, fire control, digital or analog computers, or related fields.

These positions offer many unusual attractions including high salary, unusual opportunity in military and peacetime fields, security, employee benefits, and pleasant working conditions.

Qualified individuals interested in advancing themselves now should not overlook these opportunities.

JACOBS

INSTRUMENT CO.

Bethesda, Maryland

Universal dependability

The "Planet" trade name marks the most completely reliable line of popular type, dry electrolytic condensers that high-quality materials, the best workmanship, and long experience can produce.

All "Planet" Capacitors carry a 1-year replacement guarantee, are attractively packaged, and manufactured in specifications and mounts best suited to your needs.

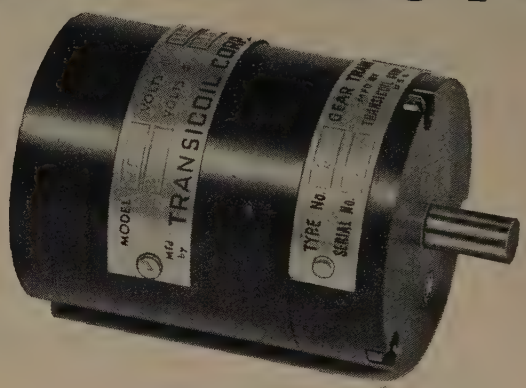
For complete information write today for our latest catalog "C-2".

PLANET

PLANET MFG. CORPORATION
225 Belleville Ave.
Bloomfield, New Jersey

...the perfect combination!

TRANSICOIL *Servo* CONTROL MOTORS



...AND *precision* GEAR TRAIN ASSEMBLY

Your best answer to precise, dependable servo operation is the Transicoil control motor and gear train combination, either as separate matching units or in a single case. Each is built for the other. Together they combine to match your specifications exactly—mechanically and electrically.

Transicoil servo motors are supplied in 2-phase line operation or plate-to-plate types for either 60-cycle or 400-cycle use. Output ratings range from fractions of a watt to 10 watts.

Gear assemblies are beautifully miniaturized, built like fine watches for negligible backlash, designed to mount the motor and data elements and to provide the necessary shaft output. Transicoil gear trains can also be supplied separately for use with other control motors. Simply specify torque, backlash, stop and other requirements for the next best thing to a complete Transicoil motor-gear train combination!

Other Transicoil precision products include induction generators and servo amplifier systems, each made to your exact specifications.

Write for Transicoil Bulletin M

TRANSICOIL CORPORATION
107 GRAND STREET, NEW YORK 13, N.Y.

PHYSICISTS AND SENIOR RESEARCH ENGINEERS

POSITIONS NOW OPEN

Senior Engineers and Physicists having outstanding academic background and experience in the fields of:

- Microwave Techniques
- Moving Target Indication
- Servomechanisms
- Applied Physics
- Gyroscopic Equipment
- Optical Equipment
- Computers
- Pulse Techniques
- Radar
- Fire Control
- Circuit Analysis
- Autopilot Design
- Applied Mathematics
- Electronic Subminiaturization
- Instrument Design
- Automatic Production Equipment
- Test Equipment
- Electronic Design
- Flight Test Instrumentation

are offered excellent working conditions and opportunities for advancement in our Aerophysics Laboratory. Salaries are commensurate with ability, experience and background. Send information as to age, education, experience and work preference to:

NORTH AMERICAN AVIATION, INC.
Aerophysics Laboratory
Box No. N-4, 12214 South Lakewood Blvd.
Downey, California

ELECTRICAL AND ELECTRONICS ENGINEERS

PARTICIPATE in the IMPORTANT COMMUNICATIONS INDUSTRY

MICROWAVE . . .
Develop assembly and test methods for radio relay equipment. Experienced in performance of amplifiers, modulators, filters and cavities operating at ultra high frequencies.

FILTERS & NETWORKS . . .
Develop methods of manufacture.

TEST . . .
Develop test facilities used in manufacture of communications and television transmission equipment. Basic knowledge of transmission theory required.

Write Dept. P giving details of qualifications, experience and salary expected, or

Apply in Person
Employment Department
Monday through Saturday
8:30 A.M. to 3:00 P.M.

Bring in proof of citizenship and your Social Security card. Veterans should present discharge papers.

WESTERN ELECTRIC CO.
100 Central Ave., South Kearny, N.J.

ENGINEERS . . .
PHYSICISTS . . .
CHEMISTS . . .
METALLURGISTS . . .

a reminder from GENERAL ELECTRIC

Tremendous material resources . . . the stimulation of highly creative work . . . long-range security and professional recognition . . . these are but a few of the assets General Electric offers you in unusual positions now available in:

Advanced Development, Design, Field Service and Technical Writing

If you have a Bachelor's or Advanced Degree in Electrical or Mechanical Engineering, Physics, Metallurgy or Physical Chemistry and experience in the Electronics Industry, you can expand your training and experience to the fullest in openings in connection with:

MILITARY RADIO & RADAR • MOBILE COMMUNICATION • MULTIPLEX MICROWAVE COMMUNICATIONS • ELECTRONIC COMPONENTS • TELEVISION, TUBES and ANTENNAS

Please send resume to:
TECHNICAL PERSONNEL
ELECTRONICS PARK

GENERAL ELECTRIC
Syracuse, New York

POSITIONS OPEN

(Continued from page 74A)

ENGINEERS

The Naval Research Laboratory have a number of vacancies in the physical sciences and engineering fields at salaries ranging from $3100 to $8800 per year. For further particulars write to: Personnel Division, Naval Research Laboratory, Washington 20, D.C.

ENGINEERS AND PHYSICISTS

Unusual opportunities in audio, sonar, and instruments with small growing company. Permanent positions. In on ground floor opportunities. Send full résumé to Personnel Dept. H. H. Scott, Inc., 385 Putnam Ave., Cambridge, Mass.

DESIGNERS AND DRAFTSMEN

Highest pay, security and top opportunity for mechanical and electronic designers and draftsmen to layout assembly and manufacturing drawings of radio and electronic equipment from sketches, schematics, parts lists, specifications, working models. Apply in person, or submit résumés and samples by mail to Boland & Boyce, Inc., 14 East Park St., Newark, New Jersey.

TRANSFORMER AND CHIEF ENGINEER

Needed to direct activities of transformer design group. Supervisory experience and technical knowledge of audio and radio frequencies transformers desired. Very good position for the right man. Salary open. Send reply to Box 679.

NATIONAL UNION RESEARCH DIVISION

The Research Laboratories of one of the nation's larger electron tube manufacturers have vacancies for electronic engineers and engineering physicists qualified in the following fields:

Vacuum tube development
Electronic circuit design
Electronic equipment

This organization can offer excellent prospects for security and personal advancement due to our continued growth. Our location is in the New York metropolitan area.

Whether you have a background of electron tube or circuit design, or are a recent graduate and interested in our field, we would like to hear from you. Send your résumé to:

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NATIONAL UNION
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(Continued on page 102A)

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THE WORKSHOP ASSOCIATES
Division of The Gabriel Company
Specialists in High Frequency Antennas
135 Crescent Road
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Positions Wanted

(Continued from page 101A)

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B.E.E. large midwestern university. 3 years' design and development of automobile broadcast receivers and some mobile communications equipment. Desires position in design and development requiring some administrative ability. Midwest, Michigan prefered. Box 545 W.

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(Continued on page 103A)

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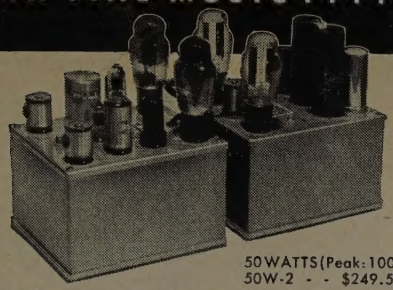

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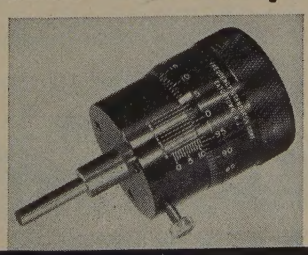

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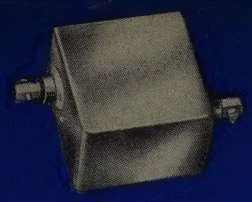

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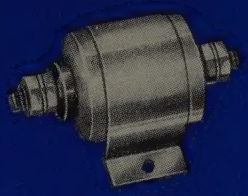

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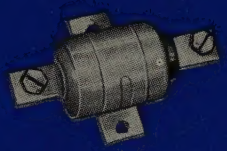

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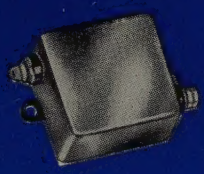

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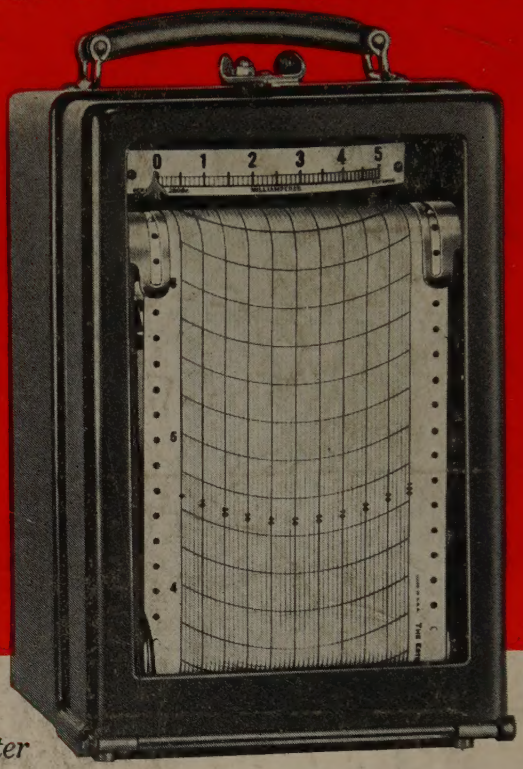

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